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ORIGINAL PAPERS

THE THERMAL CONDUCTIVITY OF CARBORUNDUM REFRACTORIES[1]

BY M. L. HARTMANN[2] AND O. B. WESTMONT[3]

ABSTRACT

Thermal conductivity measurements up to 1350°C of silicon carbide refractory materials have been made, using the water calorimeter method. Data were secured on furnace walls such as those commonly used in practice and results are believed to be accurate to within about 1%. Conductivity measurements were made on seven carborundum single walls and on eight carborundum-fire-clay composite walls. The relation of the thermal conductivity to temperature, chemical composition, and porosity was investigated, as well as the magnitude of the surface and joint effects. The conductivity of carborundum was found to vary with the quantity of heat energy transmitted through the wall. Tables are given showing the coefficients of thermal conductivity and heat flow through various types of walls with a temperature of 1500°C in the combustion chamber.

Temperature gradient charts and heat flow curves for various walls are also given together with the practical application of the results in the design of commercial furnaces.

Introduction

Conductivity of Silicon Carbide Refractories

Of all the refractory materials available commercially, there are none which even approach silicon carbide or carborundum in its ability to

[1] Received Jan. 8, 1925. This paper was presented at the Annual Meeting of the AMERICAN CERAMIC SOCIETY, Columbus, Ohio, February, 1925.

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[3] Research Chemist, Research Laboratory, The Carborundum Co., Niagara Falls, N. Y.

readily transmit heat and at the same time have mechanical strength and chemical inertness to resist the various destructive forces in modern industrial furnaces. The great mechanical strength of commercial refractories made from carborundum has been previously studied.[1] Accurate information concerning their ability to transfer heat under actual operating conditions has been lacking.

A number of investigators have studied the thermal conductivity of refractory materials, but insofar as silicon carbide refractories are concerned the results are not concordant, nor has the investigated range of temperatures been sufficiently high. The variation in the published results is perhaps due not only to the difference in the methods used, but also to the differences in the firing temperature, porosity, and chemical composition of the refractories tested.

The thermal conductivity of silicon carbide refractories at low temperatures recorded by Wologdine[2] agrees with the data published several times by The Carborundum Company.[3] These data, however, are quite different from those published recently by Beecher.[4] The results of Watts and King[5] are relative and cannot be compared directly with the values of other investigators. The curve published by M. L. Hartmann[6] represents values secured during the preliminary experimental work recorded herein.

The remarkable increase in the use of carborundum refractories in furnaces requiring a transfer of thermal energy through partition walls makes it desirable to determine accurately not only the relation of the thermal conductivity to temperature, but also its relation to the composition and to the porosity.

Application of Fourier's Law

In many installations, carborundum refractories are insulated so as to prevent rapid heat flow, with the result that the temperature gradient is relatively small. In calculating heat balances in such furnaces, it has been assumed by Fourier's law that the thermal conductivity of the refractory is independent of the temperature gradient and that the heat flow through the composite walls is inversely proportional to the thermal resistivity of each wall.

---

[1] Hartmann and Hougen, *Amer. Electrochem. Soc.*, **37,** 707 (1920); Hartmann and Kobler, *ibid.*, **37,** 717 (1920); Hartmann and Koehler, *ibid.*, **40,** 457 (1921).

[2] Wologdine, *Electrochem. and Met. Ind.*, **7,** 383 (1909).

[3] Linbarger, *Chem. and Met. Eng.*, **19,** 489 (1918); *Circular*, The Carborundum Co. (1921).

[4] Beecher, *Jour. Amer. Ceram. Soc.*, **7** [1], 19 (1924).

[5] Watts and King, *Jour. Amer. Ceram. Soc.*, **6** [10], 1075 (1923).

[6] Hartmann, "Refractories for Electric Furnaces," Booklet, The American Electrochem. Soc., p. 69 (1924).

There appears to have been very little experimental work published to determine if the thermal conductivity at a given temperature is a constant regardless of the quantity of energy being transferred. According to the Bureau of Mines Report,[1] the question of the variation of thermal conductivity with different temperature gradients has been raised by E. B. Wilson, recently of the Department of Physics of the Massachusetts Institute of Technology. Fourier's law $\left(Q = k\frac{A(t_1 - t_2)}{L}\right)$[2] assumes that the conductivity k, while of course different at different temperatures, is strictly a constant for all values of the temperature gradient $\frac{(t_1 - t_2)}{L}$. Prof. Wilson has pointed out that there is a possibility that this law of heat conduction may not be exactly realized when large temperature gradients are involved.

In single carborundum walls the transferred heat energy is much greater than in the more usual refractory materials, and hence, it seemed desirable to determine whether or not Fourier's law does hold under these unusual conditions. To do this it was necessary to test several composite walls in which the heat flow was decreased by insulation.

Method of Measuring Thermal Conductivity

The most practicable method of measuring the thermal conductivity of refractories under conditions approaching those in practice is the method used by Boyd Dudley, Jr.[3] This method does not require the use of special shapes which may have different thermal properties from those of the commercial brick. The wall under test was built of standard $2^1/_2$ x $4^1/_2$ x 9-inch brick laid up with cement of the same composition as the brick.

The heat transmitted through a definite area of this wall was measured by a waterflow calorimeter eight inches square fitted with a two-inch guard ring. This guard ring prevents lateral flow of heat. The temperature gradient through the wall was measured by thermocouples inserted to various depths in holes bored to within $^1/_4$ inch of the inner face.

For the determination of the thermal conductivity up to 1400°C, it was found that the two-inch guard ring used by Dudley did not insure normal flow of heat through that section of the wall under test. (The highest temperatures obtained by Dudley were not over 1000°C.) For this reason, an additional guard ring was used in our apparatus for the high temperature tests.

---

[1] Hersey and Butzler, "Report of Investigations," Ser. No. 2564, Jan., 1924.

[2] Throughout this paper Q = heat flow, k = thermal conductivity, A = area, L = thickness, $t_1 - t_2$ = temperature drop.

[3] Dudley, *Jour. Amer. Electrochem. Soc.*, **27**, 285 (1915).

Experimental Determinations

Apparatus

The furnace used for the conductivity tests is shown in Figs. 1 and 2. This furnace was larger than required so a partition wall was built in the center and only the portion near the test wall was used. One large oil burner operated with 6.6 lbs. air pressure was used to heat this portion of the furnace. A checkerwork was made with carborundum brick as shown so that the oil flame passed below a bridge supporting the checker and around the checker to flues. It required approximately twelve hours to heat this furnace to 1500°C in the combustion chamber. The pressure in this furnace at 1500°C was found to be +0.05 inch water.

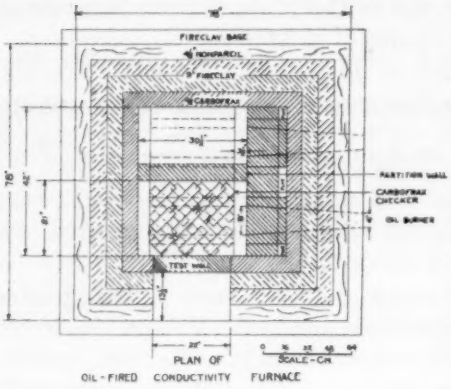

FIG. 1.

The calorimeter (Fig. 4) used was designed after the one described by Dudley. It consisted of a brass casting with a $^1/_{16}$-inch copper plate soldered to the top of the casting and constructed so as to provide for thorough circulation of water.

When the apparatus was connected up for the test, the water entered through the pipe *M*, passed around the center partition *P* to the lower compartment at *K* and returned around *P* to *N*. The rise in temperature of the water passing through the calorimeter was measured by a differential couple. This couple was inserted into rubber stoppers, which were fitted to the $1^1/_2$-inch wells on the inlet and outlet pipes (Fig. 4). These pipes were insulated with $^1/_2$-inch asbestos rope so that the temperature of the water would not change appreciably in passing from the calorimeter to the couple wells.

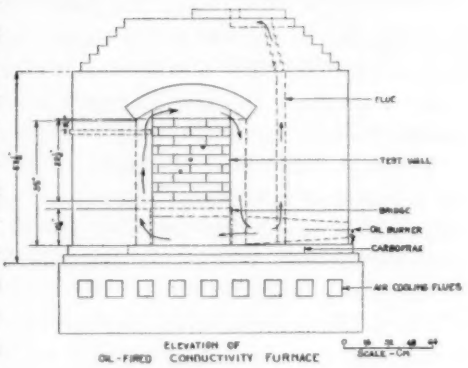

FIG. 2.

The inner and outer guard rings were constructed as shown in Fig. 5. Double circulation of water was obtained in these rings as in the calorimeter. In the inner ring the water entered at *O*, passed through the upper compartment to *S* and returned in the lower compartment to *P*.

The temperature of the outlet water from this ring was held within 0.2°C to that in the calorimeter by means of another differential couple. The calorimeter and inner guard ring were connected to a 60-gallon supply tank in which a constant pressure was maintained.

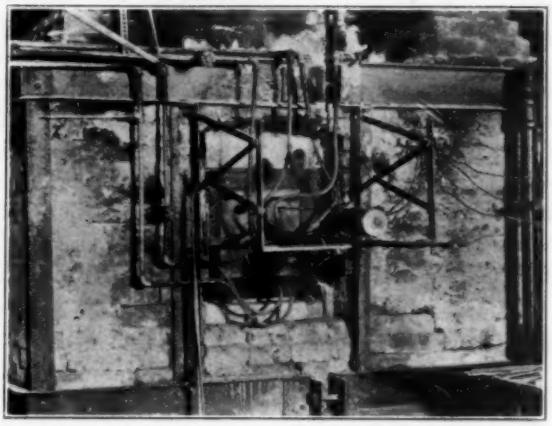

FIG. 3.

The outer guard ring was constructed so that the water entered at *Q*, passed through the compartments as in the inner ring, but in the opposite direction, and out through *R*. The flow of water in this ring was regulated so that the outlet water temperature was within 5°C of that of the calorimeter. The temperatures of the outlet water of the calorimeter and outer ring were determined by means of thermometers inserted in the water pipes near the apparatus. The outer ring was connected directly to the main water line.

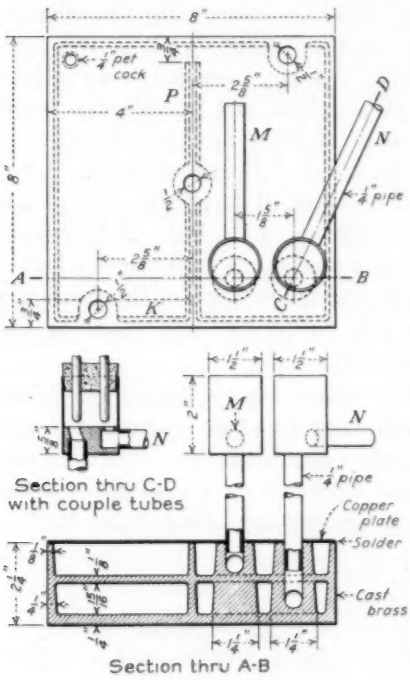

FIG. 4.—Calorimeter.

The apparatus was connected to the water lines with ⅜-inch thin-wall rubber tubing. On the outlet water tubes of the calorimeter and rings screw clamps were placed for close regulation of the flow of water. It was found that if these clamps were put on the inlet tubes the apparatus would not be filled completely with water. This was due to the siphon effect of the drain pipes. The pet cocks were necessary on the calorimeter and rings to release the air while filling the apparatus with water. The pet cocks on the rings were kept open slightly during the tests so that air pockets were prevented. Drain tubes from

these pet cocks were provided. There were no air pockets formed in the calorimeter after it was once filled with water.

Operation of Calorimeter

In using the calorimeter with the rings described there could be heat supplied to the calorimeter only through the two faces (1) from the test wall and (2) from the warm air surrounding the apparatus. In order to decrease the heat supplied by the air a $^1/_8$-inch asbestos cover plate was fitted over the top face of the calorimeter and inner guard ring. There was no insulation placed over the outer ring. Asbestos twine was packed between the inner and outer rings and around thermocouple tubes to prevent convection currents as much as possible. Asbestos rope was used for packing between the test wall and the outer guard ring.

In order to determine the amount of heat transmitted to the calorimeter from the test wall, it was first necessary to determine the exact amount of heat which would be transferred through the cover plate for various temperature differences.

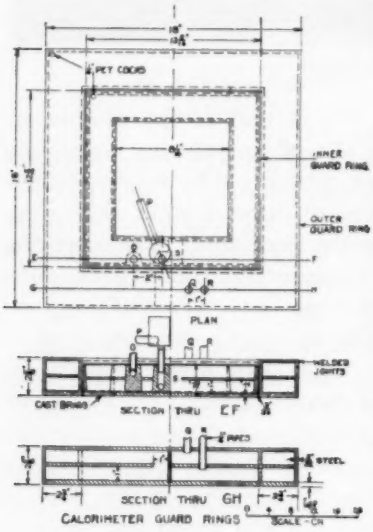

FIG. 5.

To do this the calorimeter was fitted up with differential couples and water connections just as for a regular run. Instead of mounting the calorimeter on the furnace wall, it was suspended in a large wooden box enclosed on all six sides, and an asbestos board (same as on front face) was placed over the back face of the calorimeter. A hot plate and a small electric fan were placed in the bottom of the box. A thermometer was placed one inch from each face which was the position of the thermometer relative to the front face in the later tests.

The temperature of the box was raised above that of the water entering the calorimeter and maintained at a constant value. The water entering the calorimeter and the guard ring was then adjusted so that the temperature difference at the outlet was less than 0.1°C. The results of the tests and calculations are as follows:

Minimum temp. diff. between air and cal., 13.3°C.
Maximum temp. diff. between air and cal., 30.5°C.
Av. heat flow for 21 tests for 128 in.^{2} × $^1/_8$″ thickness, 0.9600 cals./sec./°C.
Av. heat flow for 21 tests for 1 cm.^{2} × $^1/_8$″ thickness, 0.00116 cals./sec./°C.
Thermal conductivity of asbestos, 0.00037 cals./cm.^{3}/°C/sec.

Measurement of Temperature Gradients

The temperature gradients were measured simultaneously at the three points in the wall under the calorimeter by means of three Pt: Pt-Rd thermocouples attached to a slider and supported on the framework (Fig. 3). Three holes $^1/_2$-inch in diameter, drilled to $^1/_4$-inch from the hot surface were fitted with sillimanite pyrometer protection tubes, in which the three thermocouples were inserted to any measured position.

Measurements of temperature gradients in this manner are subject to certain small errors. The protection tubes are of different material from the brick wall; the thermocouple junction is exposed to radiations from the hot end of the hole; convection currents around the tube and the couple may alter the readings.

To determine the magnitude of these possible errors we repeated the tests which Dudley described, going to temperatures as high as 1450°C. Temperature measurements were made in a fire clay wall (1) in open holes (2) open holes with a protection tube liner (3) in a hole closed with clay pieces. The temperature readings in the three cases were identical within the limits of experimental error.

The Thermocouples

The differential couples were made of 30 B. & S. gage copper and constantan wire, which was tested and found to be practically homogeneous. The couples were made by mounting the wires on a cardboard and then fusing the ends together in an electric arc. Two separate couples were made in this manner, one composed of 24 junctions for use in measuring the rise in temperature of the calorimeter water, and the other composed of 12 junctions for use in measuring the difference in temperature of the outlet water from the calorimeter and inner guard ring.

The junctions of the couples were wrapped separately with thread and dipped in cellulose acetate solution to prevent short circuiting. The legs of each couple were then sealed in 6 mm. glass tubes with the same solution. The junctions to the lead wires of both of these couples were sealed with casein in test-tubes, which were immersed in oil in order to insure equal temperatures.

These differential couples were calibrated by the use of two "thermos" bottles, three standard thermometers and the precision potentiometer. One leg of the couple to be calibrated was inserted in a stopper with one standard thermometer so that the immersion mark on the thermometer was at the top of the water in the bottle. The other leg of the couple was arranged in the second bottle with another standard thermometer.

The water in one bottle was brought to 17–18°C and one leg of the couple and thermometer inserted. This leg of the couple was marked so that it would be placed in the colder water in the future tests. Care

was always taken to have the couple and thermometer at the same depth. The other leg of the couple and Fahrenheit thermometer were inserted in the other bottle containing water at a little higher temperature than that in the first bottle. After the temperature of the water in both bottles became practically constant the potentiometer and thermometers were read as nearly simultaneously as possible. The water in the second bottle was warmed slightly and the same procedure followed. This process was continued until the limit of the Fahrenheit thermometer scale was reached. With greater temperature differences the −18°C to 110°C thermometer was used in the warm water. The same procedure was continued until a temperature difference of 40°C was obtained. The calibration curves for the large couple were plotted on a large scale so that temperatures could be read directly to 0.05°C. The e. m. f. generated by the large couple was practically twice that of the small couple for the same temperature difference. A galvanometer deflection of 1 cm. with the small couple was equivalent to an average of 0.02°C temperature difference. For 0°C difference in temperature the deflection was practically nil.[1]

Method of Conducting Tests

The Walls

The thermal conductivity tests were made on the following walls:

1 9 -inch carborundum No. 1A
2 4½-inch carborundum No. 1B
3 4½-inch carborundum No. 1C
4 4½-inch carborundum No. 2
5 4½-inch carborundum No. 3
6 4½-inch carborundum No. 4
7 4½-inch carborundum No. 5
8 9 -inch carborundum No. 1A and 4½-inch fire clay No. 26
9 9 -inch carborundum No. 1A and 4½-inch fire clay No. 75
10 4½-inch carborundum No. 1C and 4½-inch fire clay No. 26
11 4½-inch carborundum No. 2 and 4½-inch fire clay No. 26
12 4½-inch carborundum No. 2 and 4½-inch fire clay No. 75
13 4½-inch carborundum No. 3 and 4½-inch fire clay No. 26
14 4½-inch carborundum No. 4 and 4½-inch fire clay No. 26
15 4½-inch carborundum No. 5 and 4½-inch fire clay No. 26

The brick used were all standard 2½ x 4½ x 9-inch.

Before making up the test walls the brick were arranged in the position in which they were later to be placed in the wall. It was necessary to grind down the edges of several of the brick so that they would fit together closely. The brick were then placed approximately 1/32 inch apart to allow for the layer of cement, and, by the use of a templet, the positions of the three holes for measuring the temperature gradient were marked.

[1] This electrical measuring equipment was designed and installed by W. G. Soley, of this laboratory, whose valuable assistance is hereby acknowledged.

In the 9-inch walls the brick were placed so that the temperature gradient was through the 9-inch dimension. In the $4^1/_2$-inch walls they were placed so that the gradient was through the $4^1/_2$-inch dimension.

In the tests on composite walls the carborundum walls were insulated with fire clay brick. These brick were arranged so that the gradient was through the $4^1/_2$-inch dimension. The temperature gradient holes through the insulating walls were made to coincide with those in the carborundum wall. The joints of the two walls were made to mis-match as much as possible.

The carborundum test brick were all laid up with a fine plastic carborundum cement of similar composition to that of the brick. A plastic fire clay cement was used in laying up the fire clay brick. After the wall was completed the surface under the calorimeter and guard rings was covered with a thin layer of the same cement which was later smoothed off and made perfectly flat with a steel straight-edge.

After completing the conductivity test on the single wall, the insulating wall was laid up in the same manner. A thin layer of fire clay cement was also placed between the walls to insure perfect contact.

Set-Up of Calorimeter After drying the test wall, the calorimeter and guard rings were placed against it so that the temperature gradient holes in the brick coincided with those in the calorimeter. The apparatus was then held firmly against the wall by means of clamp screws that were fitted to the framework shown in Fig. 3.

Heating of Furnace After the calorimeter and guard rings were adjusted the apparatus was connected to the water lines. The furnace was heated for approximately 12 hours to obtain 1500°C in the combustion chamber. The oil supply to the burner was then regulated so that the temperature of 1500°C ±15°C would be maintained throughout the test. The air supply to the burner was kept constant. In the meantime, the clamp on the outlet tube from the calorimeter was regulated so that the flow of water was not over three kilograms per minute. The clamp of the outlet tube of the inner guard ring was also regulated so that the temperatures of the water from the calorimeter and guard ring were approximately the same. The flow of water through the outer guard ring was hand regulated throughout the test so that the temperature was within 5°C of that of the calorimeter.

After the furnace had been kept at equilibrium for approximately $^1/_2$ hour, the rise in temperature of the calorimeter water was determined by the potentiometer and the difference in temperature of the calorimeter and guard ring outlet water also determined. Close adjustments were then made on the outlet tube of the inner guard ring until the temperature difference in the outlet water of the two compartments was within 0.2°C, *i. e.*, 10 cm. deflection as indicated by the galvanometer. If the change

in potentiometer reading was not over 1 cm. or 0.1°C in $^1/_2$ hour, the furnace and apparatus was considered to be in equilibrium and ready for the test. It usually required two to two and one-half (2 to $2^1/_2$) hours to secure equilibrium after the furnace was heated to 1500°C.

The Set-Up of Thermocouples

The three thermocouples for measuring the temperature gradient were fitted with $^1/_8$-inch 2-hole insulators and inserted in the protection tubes and pushed back as far as possible into the holes in the wall. The insulators were then clamped to the slider and the elements were bent so as to prevent any movement through the insulators. The cold junctions of the couples were inserted into glass tubes in a "thermos" bottle filled with ice.

With the couples arranged in this manner, they were connected to a potentiometer and the temperature readings taken simultaneously in three points in the wall.

After the apparatus was in equilibrium and the couples arranged as described above, the actual test was started. The first temperature gradient readings were taken with the couples in the wall at full depth. The slider was then pulled out 0.4 inch and readings taken. This was repeated until the slider reading was 4 inches, after which the couple was moved to its original position and the readings taken. During this time the water passing through the calorimeter was collected and weighed. After balancing the dry cells of the potentiometer against the standard cell, the slidewire readings were taken for zero deflection of the galvanometer. The temperature difference between the outlet water of the calorimeter and inner guard ring was also read. If the deflection was greater than 10 cm. or 0.2°C adjustments were made on the clamp on the outlet tube of the guard ring to equalize the temperatures. Temperature readings were taken every five minutes for one hour. The total weight of water flowing through the calorimeter during that time was then obtained.

With the thermocouples in their original position the same process was repeated as a check test. Thus for $4^1/_2$-inch walls two one-hour tests were made with the furnace at practically a constant temperature. For the composite walls each test required $1^1/_2$ hours. The temperature gradient readings were taken every 0.5 inch instead of every 0.4 inch as in the $4^1/_2$ inch-walls.

After completing the tests on a wall, the couples were marked at the end of the protection tubes when they were at full depth. The protection tube was also marked at the face of the calorimeter. The couples and tubes were then removed and measurements taken to determine accurately the depth of the hot junction of each couple in the wall at the initial position.

Calculation of Thermal Conductivity

With the temperature of the inner guard ring equal to that of the calorimeter the total heat flow Q_T from both faces of the calorimeter was equal to the sum of the heat flow from the test wall Q_W and that from the air Q_A through the opposite face. The value of Q_T was found by the formula:

$$Q_T = \frac{W \times t}{T \times A}$$

where W = wt. of water in grams
t = °C rise in temp. of water
T = time in seconds
A = area of the calorimeter in sq. cm.

Therefore, Q_T is in gm. calories /cm.²/sec.

Q_A was determined by the formula:

$$Q_A = K_1(t_1 - t_2)$$

where K_1 = ther. condy. of $^1/_8$" asbestos cover in gm. cals./cm.²/°C/sec.
t_1 = temp. in °C of air 1 inch in front of calorimeter
t_2 = av. temp. in °C of calorimeter
$= t_3 - \frac{t}{2}$ where t_3 is the temp. of the outlet water of the calorimeter.

Therefore, $Q_T - Q_A = Q_W$ in gm. cal./cm.²/sec.

The data and calculations of $4^1/_2$" of carborundum No. 4, Run No. 29, Test No. 55, are as follows:

Net wt. of water	129,630 gms.
Av. temp. of calorimeter outlet water	30.2°C
Av. temp. of air 1" in front of calorimeter	56.2°C
Av. rise in temp. of cal. water	14.97°C
Av. temp. of cal. $= 30.2 - \frac{14.97}{2}$	22.7°C
Area of calorimeter (effective)	64 sq. in.
Time of test	60 min.
Conductivity of asbestos cover ($^1/_8$" thick)	0.00116 cal./cm.²/°C/sec.

$$Q_T = \frac{129{,}630 \times 14.97}{60 \times 60 \times 64 \times 2.54^2} = 1.306 \text{ cals./cm.}^2\text{/sec.}$$

$Q_A = 0.00116\ (56.2 - 22.7) = .039$ cals./cm.²/sec.
$Q_W = Q_T - Q_A = 1.267$ cals./cm.²/sec.
Q_W (Test No. 56) = 1.270 cals./cm.²/sec.
Av. = Q_W (2 tests) = 1.269 cals./cm.²/sec.

Since the temperature gradients and the heat flow for the two tests did not usually vary over 2–3%, the averages were taken for the determination of the thermal conductivity. When there was a greater variation than this the run was repeated. The average temperature gradient curves for the single and composite walls are shown in Figs. 6, 7 and 8. These curves are extrapolated through the last $^1/_4$ inch to the fire side of the

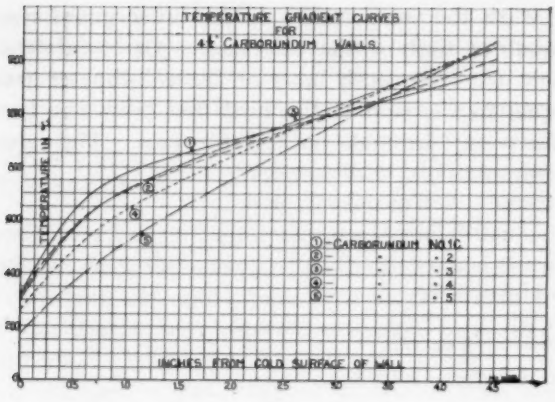

FIG. 6.

wall. They were originally plotted so that temperatures could be read directly to 2°C and distances to 0.01 inch. By the use of these curves the gradient or temperature drop per unit distance could be determined very accurately at any temperature and the conductivity, K, calculated as follows:

$$K = \frac{Q_W \times L \times 2.54}{(t_1 - t_2)}$$

where L = distance in wall in inches; $t_1 - t_2$ = temp. drop in °C.

Therefore, K is in gm. cals./cm.^{2}/°C/sec.

RUN NO. 29, AVERAGE OF TESTS NO. 55 AND 56

Temperature, °C	Av. temp., °C	Temperature gradient (Av. of 6 curves) Temp. diff., °C	Distance, in.	Thermal conductivity K in gm. cal./cm.^{2}/°C/sec.
780– 822	801	42	0.22	0.0169
880– 920	900	40	.22	.0177
986–1014	1000	28	.16	.0184
1080–1118	1099	38	.22	.0187
1176–1220	1198	44	.27	.0198

$$K_{801} = 1.269 \times 2.54 \times \frac{0.22}{42} = 0.0169 \text{ gm. cal./cm.}^2\text{/°C/sec}$$

This graphical method of determining the temperature gradient was found to be less involved and more accurate than the one used by Dudley. He assumed that the temperature gradient curve was a section of a parabola and calculated the equation of the curve from three known points. The thermal

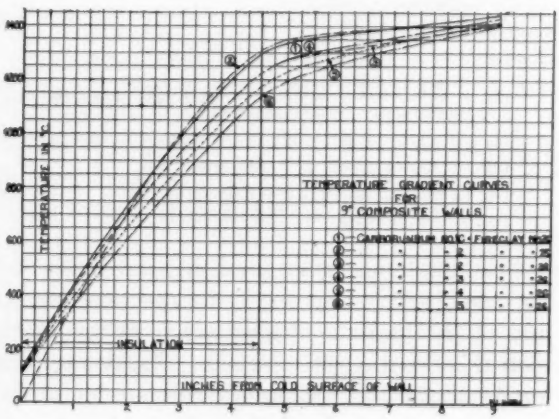

FIG. 7.

conductivity at different temperatures was then determined by taking the first derivative of the equation. Obviously starting with the assumption that the temperature gradient curve was a parabolic section, the thermal conductivity-temperature curves were necessarily straight lines since the first derivative of a second degree equation is a linear function.

In our work it was found that the thermal conductivity-temperature curves were not all linear functions. It was also found that it was practically impossible to calculate an equation for the gradient curve that would fit the actual data accurately. For these reasons the above described graphical method was used for calculating thermal conductivities.

Brick Used for Thermal Conductivity Test

The Nos. 1A, 1B, 1C brick were made of carborundum recrystallized in an electric furnace. The other carborundum brick contained ceramic bonds and were kiln fired at approximately 1350°C. The brick No. 26 were coarse, fairly open, first quality fire clay. Brick No. 75 were extremely porous fire clay products also fired at about 1350°C.

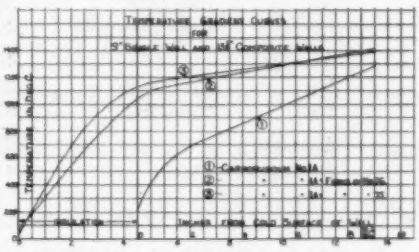

FIG. 8.

In selecting the brick for test the apparent densities of several were first determined, and only those whose apparent densities were near the average of the lot were used in the test wall. In the wall directly under the calorimeter the brick with no greater variation in apparent density than 0.04 gms./cc. were used.

After the completion of the tests on each wall the brick under the

TABLE I

	Carbo No. 1A	Carbo No. 1B	Carbo No. 1C	Carbo No. 2	Carbo No. 3	Carbo No. 4	Carbo No. 5	Fire clay No. 26	Fire clay No. 75
Apparent density (grams per cc.)	2.05	2.07	2.20	2.48	2.35	2.36	2.31	2.05	0.67
Porosity[1]	34.1	33.8	29.5	18.4	20.7	17.7	18.9	26.8	74.2
Ignition	0.17	0.00	0.00	0.88	0.24	0.02	0.10	0.31	0.00
SiO_2	8.02	4.50	4.50	14.72	23.31	36.80	38.76	58.50	56.90
SiC	91.51	93.20	93.20	80.10	68.50	52.60	48.35		
Al_2O_3	0.20	1.33	1.33	1.47	5.58	8.10	11.63	34.48	37.70
Fe_2O_3	0.65	1.03	1.03	1.33	1.57	1.97	1.97	3.52	2.37
TiO_2								1.80	1.74
CaO								0.29	0.82
MgO								0.62	0.20
Total	100.55	100.06	100.06	98.50	99.20	99.49	100.81	99.52	99.73

[1] Calculated assuming sp. gr. SiC = 3.17; sp. gr. fire clay = 2.60.

calorimeter were sampled for chemical analysis. The samples were taken from the central, vertical section of the test wall.

The average apparent densities and chemical analyses of the brick are shown in Table I.

Results

Thermal Conductivity In the preliminary work a 9-inch carborundum wall was used and checks made on two separate runs (Nos. 3 and 5). Tests were then made on the same wall backed with various kinds of insulation after which another run (No. 10) was made on the 9-inch wall to check the original results, and to determine if there was any change in the conductivity due to changes in the refractories. The results of the three runs on the 9-inch wall are given in Table II.

TABLE II

Run no.	Temperature, °C	Heat flow Gm. cal./cm.²/sec.	Thermal conductivity Gm. cal./cm.²/°C./sec.	
3a	640–1295	1.525	0.0416	
3b	665–1340	1.582	.0417	
5a	685–1320	1.392	.0390	
5b	678–1330	1.498	.0408	
Average		1.499	.0408	±0.0004
10a	672–1205	1.305	.0404	
10b	710–1283	1.358	.0391	
Average		1.332	.0398	± .0005
Average of 3 runs		1.415	.0403	± .0004

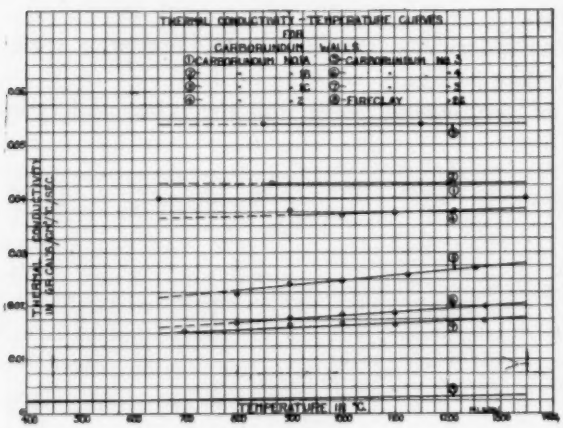

FIG. 9.

These tests show that the results on a given wall can be relied upon to within approximately 1%.

The results on single and composite walls are shown in Table III. The curves showing the change in thermal conductivity with temperature are shown in Figs. 9, 10 and 11. It will be noted in Fig. 9 that the thermal conductivity for carborundum brick does not change rapidly with temperature. With the practically pure carborundum refractory the thermal conductivity is constant at temperatures from 650°C to 1350°C.

TABLE III

Carborundum wall	Insulation	Per cent SiC	Av. heat flow: Gm. cal./cm.²/sec.	Av. heat flow: B.t.u./ft.²/hr.	Temp. gradient at 1350°C (2462°F): °C/cm.	Temp. gradient at 1350°C (2462°F): °F/in.	Ther. condy. of Carbo wall at 1350°C (2462°F): Gm. cal./cm.²/°C/sec.	Ther. condy. of Carbo wall at 1350°C (2462°F): B.t.u./ft.²/in./°F/hr.
9″ Carbo No. 1A	None	91.51	1.415	18,780	35.2	160.7	0.0403	116.9
9″ Carbo No. 1A	4½″ Fire clay No. 26	91.51	0.215	2,850	14.0	64.1	0.0153	44.4
9″ Carbo No. 1A	4½″ Fire clay No. 75	91.51	0.075	990	10.1	46.2	0.0074	21.5
4½″ Carbo No. 1B	None	93.20	1.801	23,900	41.9	191.7	0.0430	124.8
4½″ Carbo No. 1C	None	93.20	2.314	30,710	42.7	195.1	0.0542	157.3
4½″ Carbo No. 1C	4½″ Fire clay No. 26	93.20	0.293	3,890	9.4	42.7	0.0314	91.1
4½″ Carbo No. 2	None	80.10	2.170	28,800	56.8	260.0	0.0382	110.9
4½″ Carbo No. 2	4½″ Fire clay No. 26	80.10	0.241	3,200	12.0	54.8	0.0201	58.3
4½″ Carbo No. 2	4½″ Fire clay No. 75	80.10	0.074	980	5.8	26.5	0.0127	36.9
4½″ Carbo No. 3	None	68.50	1.476	19,590	52.5	240.0	0.0281	81.5
4½″ Carbo No. 3	4½″ Fire clay No. 26	68.50	0.254	3,370	13.8	63.1	0.0184	53.4
4½″ Carbo No. 4	None	52.60	1.269	16,840	62.2	284.5	0.0204	59.2
4½″ Carbo No. 4	4½″ Fire clay No. 26	52.60	0.289	3,840	15.4	70.4	0.0187	54.3
4½″ Carbo No. 5	None	48.35	1.369	18,170	77.0	352.0	0.0178	51.7
4½″ Carbo No. 5	4½″ Fire clay No. 26	48.35	0.302	4,010	17.0	78.3	0.0176	51.1

Effect of Gas Diffusion

We believe that the high values for the carborundum brick No. 1C are due to gas diffusion outward toward the calorimeter.

The surface of this wall on the fire side was not coated with cement as in the case with the other walls. Attention has been called by Howe and Phelps[1] to the abnormal effects on thermal conductivities due to penetration of hot gases through the refractories.

[1] Howe and Phelps, *Jour. Amer. Ceram. Soc.*, **5**, 420 (1922).

Effect of Porosity of Refractory

In order to determine the relation between the thermal conductivity at a given temperature and the percentage of silicon carbide in the carborundum brick, it was necessary to consider the effect of the porosity of the brick. In the case of the fire clay brick with 26% and 74% porosities it was found that the thermal conductivity at 1350°C was approximately inversely proportional to the porosity. With the assumption that the same relation would hold for carborundum brick the thermal conductivities at 1350°C for the uninsulated walls were

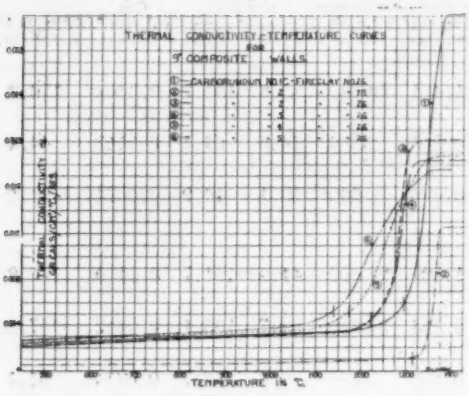

FIG. 10.

calculated for zero porosity, and finally for 15, 20, 25, 30 and 35% porosity as shown in Table IV. Figure 12 shows the change in conductivity with increased percentages of carborundum for these porosities.

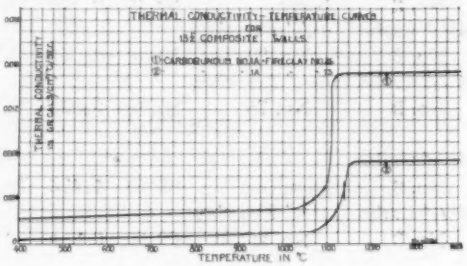

FIG. 11.

Conductivity Related to Heat Flow

Figures 10 and 11 show the very rapid rise in thermal conductivity in the carborundum portion of the composite walls. In comparing the thermal conductivities of the single and insulated carborundum walls, in Table III, it is noted that there is a marked decrease in the conductivity at a given temperature when the carborundum is insulated. This indicates that the

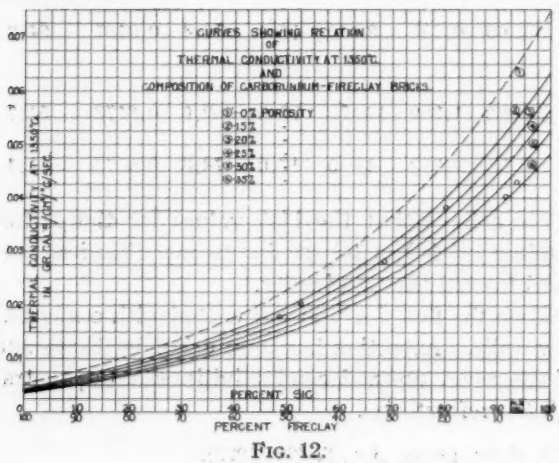

FIG. 12.

TABLE IV

THERMAL CONDUCTIVITY AT 1350°C

Single wall	Per cent SiC	Per cent porosity	Experimental value	Calc. for 0% porosity	Calc. for 15% porosity	Calc. for 20% porosity	Calc. for 25% porosity	Calc. for 30% porosity	Calc. for 35% porosity
Carbo No. 1A	91.51	34.1	0.0403	0.0649	0.0552	0.0519	0.0487	0.0454	0.0422
Carbo No. 1B	93.20	33.8	0.0430	0.0611	0.0519	0.0489	0.0458	0.0428	0.0397
Carbo No. 2	80.10	18.4	0.0382	0.0468	0.0398	0.0374	0.0351	0.0328	0.0304
Carbo No. 3	68.10	20.7	0.0281	0.0354	0.0301	0.0284	0.0266	0.0248	0.0230
Carbo No. 4	52.60	17.7	0.0204	0.0248	0.0211	0.0198	0.0186	0.0174	0.0161
Carbo No. 5	48.35	18.9	0.0178	0.0219	0.0187	0.0176	0.0165	0.0154	0.0143
Fire clay No. 26	0	26.8	0.0038	0.0052	0.0044	0.0041	0.0039	0.0036	0.0034

conductivity is related to the heat flow or temperature gradient. Figure 13 shows the relationship between the thermal conductivity at 1350°C and the heat flow. It will be noted from these curves that in the case of single walls where the temperature gradient is large, the change in conductivity with heat flow is small compared to that in case of composite walls. The conclusion to be drawn from this is that thermal conductivity data for carborundum obtained with large temperature gradients is only applicable in furnace walls where similar conditions are present. With highly insulated walls the effect of the temperature gradient on the thermal conductivity should be taken in consideration. This added variable in the calculation of heat balances will, of course, complicate furnace problems, but it is of such a magnitude in the case of carborundum that it cannot be neglected.

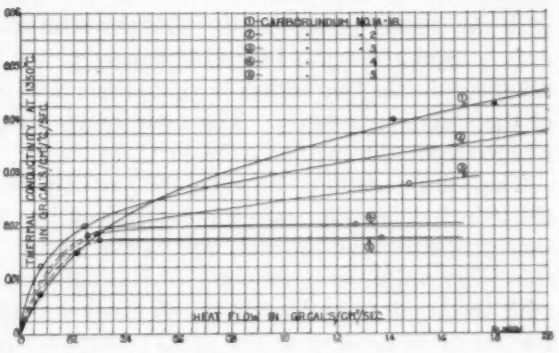

FIG. 13.—Thermal conductivity-heat flow curves for carborundum brick.

Surface and Joint Resistance

In using thermal conductivity data in these problems the question of surface and joint resistances to heat flow in the walls has often been raised. It is expected that the joint resistances of various walls would be approximately the same, but gas-film resistances at the inside surfaces

would be quite variable in different installations depending chiefly upon the velocity of the gases in the furnaces. In our experimental work the velocity of the gases was kept approximately constant, but the temperature at the hot surface was measured in only one wall. The temperature of the gases in the combustion chamber is not the same as that at the surface of the brick unless the heat flow through all the furnace walls is uniform. In the tests on the single walls the heat flow through the test wall was several times greater than that through the furnace walls so the temperature at the surface of the test wall was considerably lower than that of the furnace gases. The average difference between the temperature at the surface from the curves, Fig. 6, and that of the gases was found to be 260°C.

In the case of the composite walls the heat flow through the test wall was approximately the same as that through the furnace walls so that the average difference between the temperatures at the surface from the curves in Fig. 7 and that of the gases was approximately 80°C. To confirm this calculation a test was carried out on a $4^1/_2$- inch fire clay wall and the temperature drop at the hot surface of the brick was measured. This was done by drilling a $^1/_8$-inch hole through the last $^1/_4$-inch of the brick in the center temperature gradient hole and inserting a Pt: Pt-Rd thermocouple with $^1/_8$- inch insulators into the hole until the junction was even with the surface of the brick. The temperature gradient curve obtained as in a regular test was then extrapolated to the hot surface brick and the difference in the two surface temperatures thus obtained was the measure of the surface resistance. The temperature drop at the fire clay surface was found by this method to be 95°C.

The joint resistance between the carborundum and the insulation in the 9- inch composite walls was determined by extrapolating the temperature gradient curves in each wall to the joint. The average drop due to this joint resistance was found to be approximately 30°C. This agrees with the results obtained by F. T. Snyder[1] regarding the comparatively low temperature drop at the joints at high temperatures. In calculating the resistances to heat flow through composite walls the assumption may therefore be made that the temperature drop at the hot surface is approximately 80°C, and that at each joint is 30°C.

Application of Results

Single Walls

In the refractories through which the maximum heat transmission is desired comparatively thin single walls are used if they have sufficient strength to withstand the necessary loads. For comparison in such cases calculations (Table V) have been made

[1] Snyder, *Jour. Amer. Electrochem. Soc.*, **18,** 235 (1910).

TABLE V

Furnace temp., °F	Outside temp., °F	Surface drop, °F	Brick temp. drop, °F	Total temp. drop, °F	K_1 carbo B.t.u./ft.²/ in./°F/hr.	K_2 fire clay B.t.u./ft.²/in./ °F/hr.	Heat flow B.t.u./ft.²/hr.
			$4^1/_2$″ Carbofrax				
2732	1112	144	1476	1620	108.5		35,600
2372	968	144	1260	1404	107.4		30,100
2012	824	144	1044	1188	106.2		24,700
1652	680	144	828	972	105.0		19,340
			$4^1/_2$″ Refrax				
2732	1256	144	1332	1476	117.0		34,600
2372	1094	144	1134	1278	117.0		29,500
2012	932	144	936	1080	117.0		24,350
1652	770	144	738	882	117.0		19,200
			$4^1/_2$″ Fire clay				
2732	446	144	2142	2286		8.42	4,010
2372	392	144	1836	2980		7.84	3,200
2012	338	144	1530	1674		7.26	2,470
1652	284	144	1224	1368		6.68	1,820

on the amount of heat energy transmitted through carbofrax, refrax, and fire clay walls for temperatures of 2732°F, 2372°F, 2012°F, and 1652°F (1500°C, 1300°C, 1100°C, and 900°C), in the combustion chamber. The thermal conductivities used in these calculations were the mean values obtained from

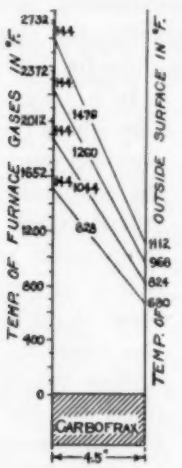

FIG. 14.

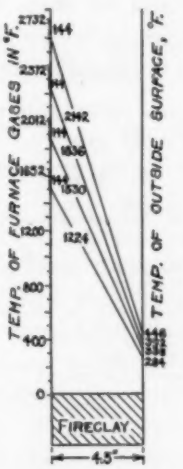

FIG. 15.

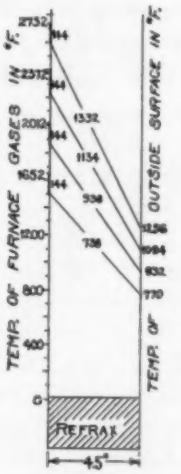

FIG. 16.

actual tests over the temperature ranges shown in Figs. 14, 15 and 16. On these gradient charts the temperatures of the outside surface are approximate with the temperature of the surrounding air about 20°C, and the brick are exposed to no appreciable amount of wind. In all

these gradients the temperature drop due to the gas film on the hot surface of the brick is assumed to be 144°F (80°C). It is, of course, understood that this value is subject to variation with different velocities of the gases in the combustion chamber. The furnace used for test was, however, operated under conditions very similar to those in commercial furnaces so 80°C represents the magnitude of the surface drop in these furnaces.

The heat flow curves (Fig. 17) show the amount of heat energy transmitted in B.t.u./sq. ft./hr. through walls with various temperature drops which include in each case the surface drop of 80°C. Thus, it is only necessary to measure the temperature of the gases and that of the outside surface and the heat loss per unit area for this temperature drop is at once found. In cases where calculations are to be made for electric furnaces the same curves can be used if the temperature of the hot surface is measured. This temperature is then 80°C lower than that of the furnace gases.

Comparison of Fire Clay and of Silicon Carbide

From these curves (Fig. 17) the enormous amount of heat transmitted through carborundum as compared to that transmitted through fire clay is shown. With a temperature drop of 1450°F there is seventeen times the amount of heat energy conducted through the refrax as through fire clay of the same thickness. In actual practice there is seldom the same drop in the two cases, but even with the temperature drop shown in Figs. 14, 15 and 16 there is approximately nine times the heat conducted through the carborundum as through fire clay. The values (Fig. 17) for carbofrax are slightly lower than those for refrax.

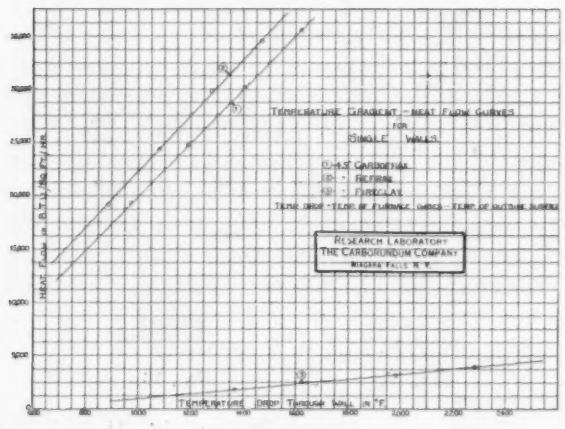

FIG. 17.

In a radiation furnace where the heat is removed quickly from the refractory surface (there being a large temperature gradient) it is at once seen from these curves how much the efficiency of the furnace would be reduced by the use of fire clay or similar refractory material. In small muffles, coke ovens, Dressler kilns, "Carbo Radiant" furnaces, etc., in which the quantity of heat transmitted through a wall is very large, the high thermal efficiency of carborundum is at once recognized.

From the charts (Figs. 14, 15, and 16) the surface temperature of carborundum as compared to fire clay will also be noted. This high temperature together with the high emissivity, which has been found to be nearly double that of fire clay, makes carborundum refractories excellent radiators of heat.

Relative Time Required to Heat Refractories

In applications in which the heat transmission is not so important as the diffusivity, it is desirable to know the relative time required to heat the refractories to a given temperature. In the calculations on carbofrax, refrax, and fire clay assumptions were made that one surface of the wall was perfectly insulated, that is, no heat lost, and the other surface heated uniformly at 1350°C (2462°F) (the operation temperature of many commercial muffles).

In making these calculations Ingersoll and Zobel's[1] formula was used.

$$T_1 = T_2\left(1 - \frac{4c}{\pi}\frac{-h^2\pi^2 t}{L^2} + \frac{4}{3\pi}c\frac{-9h^2\pi^2 t}{L^2} \ldots\right)$$

where T_1 = Temperature of insulated surface in °C
T_2 = Temperature of hot surface on °C (constant)
L = Twice the thickness of the wall
k = Thermal conductivity in C. G. S. units
c = Specific heat in C. G. S. units
d = Density
$h^2 = k/cd$

The value of the last term is negligible except when t is very small.

The thickness of the wall was assumed to be three inches. The thermal conductivities, densities, specific heats, etc., used in the calculations are shown in Table VI. It will be noted that the value of the thermal conductivity used for carbofrax and refrax decreases quite considerably with the temperature drop. These values were obtained from curves showing the relationship between temperature drop and thermal conductivity. Different values for time were then substituted in the above formula until a temperature drop corresponding to the conductivity used was obtained. The mean value of the thermal conductivity of fire clay was used over the temperature range from 20°C to 1350°C (2462°F), the conductivity of fire clay being independent of the temperature gradient. The relative heating time for these three refractories is shown in Fig. 18. From these curves it is found that the time required to heat a fire clay wall to within 162°F of the hot surface is 4.9 times that of refrax and 6.3 times that of carbofrax.

In all intermittent furnace operations the time required to heat the furnace walls to a given temperature is an important factor entering in

[1] Glazebrook's "Dictionary of Applied Physics," page 466.

TABLE VI

Carbofrax

$d = 2.45, c = 0.18, L = 6''$

Time, min.	B.t.u./ft.²/in./°F/hr.	Temp. drop, °F	T_2 °F	T_1 °F
1	111.0	2338	2462	124
3	111.0	1595	2462	867
5	111.0	1026	2462	1436
8	111.0	531	2462	1931
11	92.8(392°F)	401	2462	2051
12	92.8(392°F)	301	2462	2161
18	69.7(257°F)	252	2462	2210
40	42.4(140°F)	104	2462	2358
90	24.7(77°F)	36	2462	2426

Refrax

$d = 2.05, c = 0.16, L = 6''$

1	117.0	2200	2462	262
3	117.0	1210	2462	1252
5	117.0	644	2462	1818
6	117.0	473	2462	1989
11	81.3(392°F)	349	2462	2113
20	50.8(257°F)	238	2462	2224
40	29.0(158°F)	139	2462	2323
100	14.5(95°F)	63	2462	2399

Fire Clay

$d = 2.04, c = 0.19, L = 6''$

10	7.26	2374	2462	88
30	7.26	1876	2462	586
60	7.26	1156	2462	1306
90	7.26	706	2462	1756
120	7.26	430	2462	2032
150	7.26	263	2462	2199
180	7.26	160	2462	2302
210	7.26	97	2462	2365
240	7.26	59	2462	2403

fuel and labor costs. In selecting the best refractory to be used the first cost of the installation may be comparatively high, but this is more than offset by the economies in the operation. Such is the case with carborundum especially in heat treating, enameling muffle furnaces, etc., which perhaps costs ten times as much as fire clay, but commercial reports show 40–50% increase in production and approximately the same percentage decrease in fuel costs without considering the saving of time and labor.

The heat capacity of the charge in most of these furnaces is very low compared to that of the muffle, usually below 5%, so at least 95% of the heat supplied by the gases is absorbed by the refractory walls or lost through the doors and back wall. In the calculations on the heat capacity

of furnace walls the assumption was made that there was no loss of heat from one surface and that the other surface was uniformly heated at 1350°C.

Such conditions are approached in most oil and gas fired muffles, since the flue side of the wall is heated quite rapidly to a fairly constant temperature, and the heat loss from the wall on the other side to the charge is very low (2–5%). The loss through the doors and back wall depends upon the furnace construction, but this is usually a small percentage of the total heat supplied. At least, it would be very much the same in the two cases under consideration.

By referring to Fig. 18 then, the relative heating time required in the case of carborundum and fire clay muffles can be emphasized, that is, assuming the same thickness of the walls. Carborundum muffles are usually made with walls 1 to 1.5 inches thinner than fire clay muffles so that the heating time for these muffles is decreased still further in the actual installation.

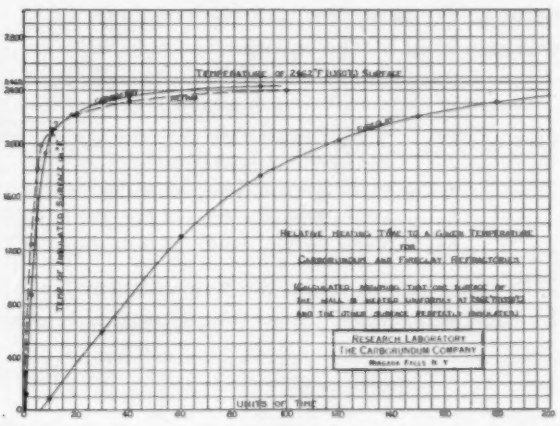

FIG. 18.

In most commercial muffles the temperature drop through the wall is usually below 100°C, while in the fire clay it is 350–400°C so that the flue temperatures must be maintained at 250–300°C higher in order to attain the proper muffle temperature in a reasonable length of time.

Composite Furnace Walls

In a large percentage of furnaces in which carborundum refractories have to be insulated, it is very necessary to select the proper kind and amount of insulation. Many insulating materials do not withstand high temperatures, others withstand the temperatures but transmit too much heat. Nine inches of insulation having a low thermal conductivity may be sufficient in one furnace, while $13^1/_2$ inches or 18 inches may be required in others. The amount of insulation may be limited to the available floor space in a particular plant. With added insulation the increase in the radiation surface may cause excessive heat losses, etc. All these factors make the question of insulation a complicated one.

In order to assist in the solution of some of these problems calculations

have been made on six insulated carborundum walls for various temperature drops.

Since it was found in our experimental work that the thermal conductivity (K) of carborundum varied with the amount of heat energy (Q) transmitted, it was first necessary to determine the equation for the relationship between these variables in further calculations in composite walls. The equations were found to be as follows:

(1) For Carbofrax: $K^2 - 0.00557K - 0.00122Q = 0$
(2) For Refrax: $K^2 + 0.0133K - 0.00204Q = 0$
(from conductivity data)

In an insulated wall composed of, for example, $4^1/_2''$ of carbofrax, $4^1/_2''$ of fire clay and $4^1/_2''$ of highly insulating material, the relationship between the heat flow and the conductivity of each portion of the wall was expressed by the equation

$$(3) \qquad Q = \frac{T_1 - T_2}{4.5 \times 2.54\,(1/K - 1/K_2 - 1/K_3)}$$

where $T_1 - T_2$ = Total temperature drop through the wall (excluding the drops at the surface and joints)
K = Mean thermal condy. of carbofrax in C. G. S. units
K_2 = Mean thermal condy. of fire clay in C. G. S. units
K_3 = Mean thermal condy. of insulation in C. G. S. units

In using this equation the temperature drop ($T_1 - T_2$) was assumed and $K_2 - K_3$ determined over the approximate temperature range in each section of the wall. Equations (1) and (3) each having the same two variables were then solved simultaneously and the heat flow through the composite walls calculated. Finally, the temperature drop through each section of the wall was determined by the formula

$$T = \frac{Q \times 4.5 \times 2.54}{K}.$$

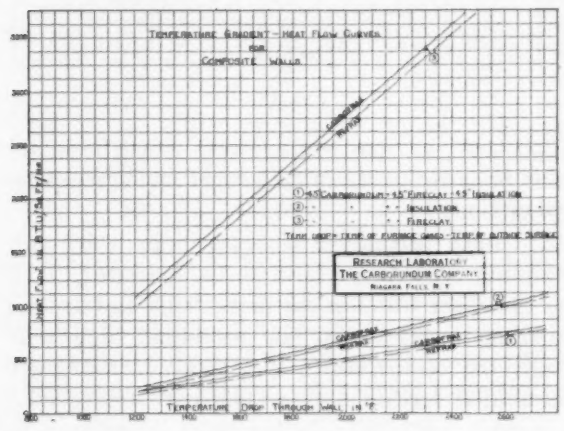

FIG. 19.

Thus, the results were checked if the sum of the temperature drops in each wall was equal to the total assumed drop.

By the use of this method, the heat transmitted through composite walls was calculated for both carbofrax and refrax backed up with fire

clay, insulation, and fire clay and insulation combined. The tabulation of the results is shown in Table VII and the heat flow curves for these six walls plotted on Fig. 19. The temperature drop shown on the curves

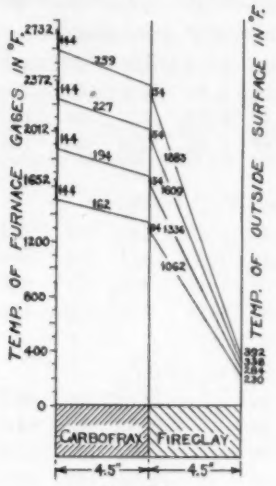

FIG. 20.

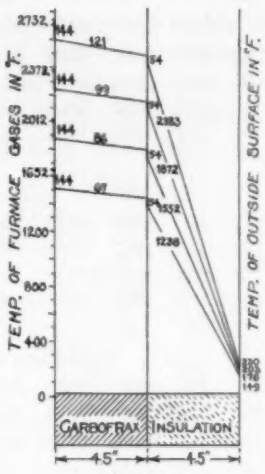

FIG. 21.

includes the surface drop of 80°C as in the single walls. The joint drop used in the gradient charts (Figs. 20–25 inclusive) was assumed to be 30°C, the average value determined by the actual tests on composite walls.

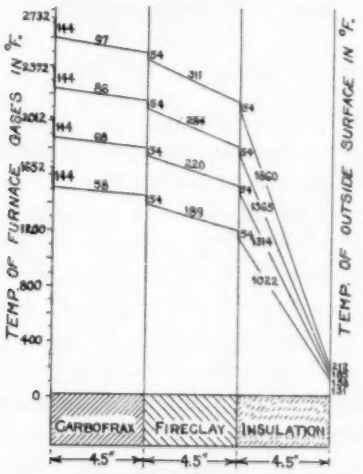

FIG. 22.

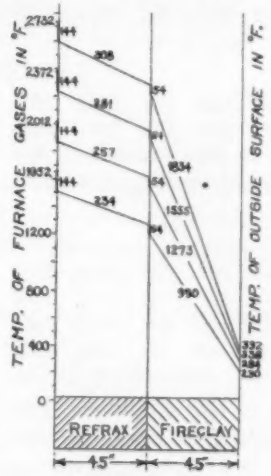

FIG. 23.

In insulating carborundum refractories the materials selected should withstand the maximum operating temperatures. Most insulators will fuse and crack excessively at temperatures above 1050 to 1100°C. As

TABLE VII

Furnace temp., °F	Outside temp., °F	Surface drop, °F	Brick drop, °F	Total drop, °F	K_1 carbo B.t.u./ft.²/in./°F/hour	K_2 fire clay B.t.u./ft.²/in./°F/hour	K_3 insulation B.t.u./ft.²/in./°F/hour	Heat flow B.t.u./ft.²/hour	T_1 carbo, °F	T_2 fire clay, °F	T_3 insulation, °F
$4\frac{1}{2}$" Carbofrax, $4\frac{1}{2}$" Fire Clay, $4\frac{1}{2}$" Insulation											
2732	212	252	2268	2520	32.8	10.44	1.74	716	97	311	1860
2372	185	252	1935	2187	31.0	9.58	1.74	604	86	284	1565
2012	158	252	1602	1854	27.9	8.72	1.45	423	68	220	1314
1652	131	252	1269	1521	25.8	7.88	1.45	329	58	189	1022
$4\frac{1}{2}$" Refrax, $4\frac{1}{2}$" Fire Clay, $4\frac{1}{2}$" Insulation											
2732	212	252	2268	2520	16.3	10.44	1.74	690	191	297	1780
2372	185	252	1935	2187	13.9	9.58	1.74	571	184	268	1483
2012	158	252	1602	1854	10.4	8.72	1.45	395	171	203	1228
1652	131	252	1269	1521	8.4	7.84	1.45	301	162	173	934
$4\frac{1}{2}$" Carbofrax, $4\frac{1}{2}$" Fire Clay											
2732	392	198	2142	2340	60.9	8.42		3520	259	1883	
2372	338	198	1836	2034	55.5	7.84		2800	227	1609	
2012	284	198	1530	1728	49.7	7.36		2150	194	1336	
1652	230	198	1224	1422	44.2	6.68		1580	162	1062	
$4\frac{1}{2}$" Refrax, $4\frac{1}{2}$" Fire Clay											
2732	392	198	2142	2340	50.3	8.42		3440	308	1834	
2372	338	198	1836	2034	43.3	7.84		2710	281	1555	
2012	284	198	1530	1728	36.0	7.26		2060	257	1273	
1652	230	198	1224	1422	28.5	6.68		1470	234	990	
$4\frac{1}{2}$" Carbofrax, $4\frac{1}{2}$" Insulation											
2732	230	198	2304	2502	36.9		2.03	987	121		2183
2372	203	198	1971	2169	33.1		1.74	725	99		1872
2012	176	198	1638	1836	31.1		1.74	602	86		1552
1652	149	198	1305	1503	27.3		1.45	401	67		1238
$4\frac{1}{2}$" Refrax, $4\frac{1}{2}$" Insulation											
2732	230	198	2304	2502	20.9		2.09	950	203		2101
2372	203	198	1971	2169	16.3		1.74	680	191		1780
2012	176	198	1638	1836	13.9		1.74	571	182		1456
1652	149	198	1305	1503	9.9		1.45	366	167		1138

shown in the gradients (Figs. 21 and 24) such materials could not be used unless the operating temperature (furnace gases) was below 1300°C. Where it is necessary to run at higher temperatures the carborundum must be backed up with a higher temperature material, usually common fire clay (Figs. 20 and 23), but the heat losses through this material are excessive. The practice then, is to use both the fire clay and insulation as shown in Figs. 22 and 25.

The principal use of the additional layer of fire clay is to lower the temperature gradient, since it does not reduce the heat losses appreciably as shown in Fig. 19. The difference between curves 1 and 2 (Fig. 19) indicates the small insulating value of this material.

In many furnaces it is necessary to use perhaps 18 inches of common fire clay in order to lower the gradient so that the insulation will withstand the temperatures. All this fire clay material does decrease the heat losses by "straight line" conductivity, but it increases the heat capacity and radiating surface so greatly that this advantage cannot be considered.

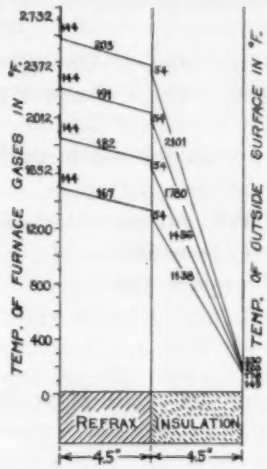

FIG. 24.

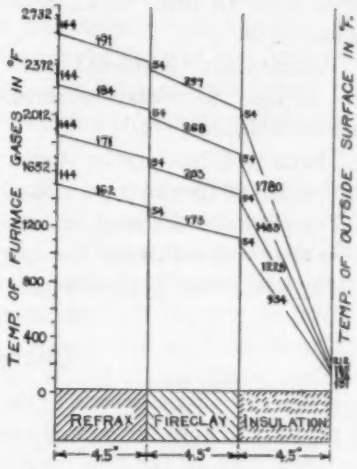

FIG. 25.

Conclusions

In addition to the numerical values for the thermal conductivity of carborundum refractories containing various percentages of silicon carbide and fire clay, we can draw from the data the following conclusions:

1. The thermal conductivity of practically pure carborundum is constant for temperatures ranging from 650° to 1350°C.
2. The thermal conductivity of ceramically bonded carborundum increases with increasing temperature.
3. The thermal conductivity of carborundum refractories decreases with the increase in percentage of fire clay bond.
4. The temperature gradient through a carborundum wall increases with the increase in percentage of fire clay bond in the brick.
5. The thermal conductivity of fire clay is approximately inversely proportional to the porosity.
6. At any given temperature the thermal conductivity of carborundum increases as the amount of heat energy transmitted is increased.

7. At any given temperature the thermal conductivity of the fire clay is practically independent of the amount of heat energy transmitted within the range investigated.

8. The temperature drop due to the gas-film resistance at the hot surface of insulated furnace walls is approximately 80°C under these experimental conditions.

9. The temperature drop due to the joint resistance in composite furnace walls is approximately 30°C under these experimental conditions.

In order to make the experimental data on carborundum refractories of more practical value in the solution of furnace problems, calculations have been made to apply to a number of commercial applications for the determination of:

10. Temperature gradient and heat transmission through single walls as applied to radiation furnaces, coke ovens, "Carbo Radiant" furnaces, tunnel kilns, etc.

11. Thermal diffusivity of single walls for comparison in muffle and other intermittent furnace operations.

12. Temperature gradient in composite walls for use in selecting the insulation that will withstand the operating temperatures.

13. The heat losses in the insulated carborundum walls.

Discussion

C. J. HUDSON:[1] By a perusal of the literature for results of conductivity data, a reader will note the lack of agreement among various investigators. The determination of the true coefficient of conductivity of a material is not an easy thing to make; the apparent result is oftentimes the sum of the true coefficient and other factors creeping in to give an erroneous result. The authors of this paper have taken great pains to eliminate some of these other factors and deserve credit for the careful work which they have done.

The coefficient of conductivity for silicon carbide, as just shown, is considerably higher than any other published result for this material. If the authors had determined the coefficients for a few other materials and had shown them to be in fair agreement with those of other authorities, this high result for silicon carbide would be somewhat more conclusive. The results given for fire clay compare favorably with some of those published by other observers, but the term fire clay is a loose one to use since fire clays differ in properties which in turn may affect their coefficients of conductivity.

A possible explanation for this high result may be in the diffusion of the furnace gases through the refractory wall under test. Howe and

[1] Norton Co., Worcester, Mass.

Phelps[1] have shown that a slight pressure in a furnace under fire will appreciably raise the temperature within refractory walls some distance from the fire side. The authors have apparently painted the outside of their refractory test walls with a cement, but this would not prevent diffusion of the furnace gases into the holes cut for the thermocouples. The fire side of the test walls seems to have been covered with cement except in one case, but it is doubtful if this covering would prevent the diffusion of gases into the thermocouple holes which were cut to within $^1/_4$ inch of the fire side. This doubtful point could have been partially corrected had the couples been inserted parallel to the plane of the furnace wall instead of perpendicular to it; this change would have also eliminated any radiation and conduction errors in the thermocouple readings.

The thermal conductivity-temperature curves given in Fig. 9 were found to be non-linear functions. This is apparently a mis-statement for all seem to be straight lines and some are constructed by drawing them through only two observation points.

The conclusion that the thermal conductivity of silicon carbide at a given temperature increases with the amount of energy transmitted is interesting. Since this seems to be a property peculiar to silicon carbide and not to fire clay an attempt at an explanation of this phenomenon would have certainly added weight to the conclusion. If the test to prove this had been carried out with the same average temperatures through the piece as was used for the determination of the conductivity coefficients, the result would have been somewhat more conclusive.

Conductivity coefficients of silicon carbide and fused alumina refractories have been published by Norton Company showing a difference of about 15% between them; while these published coefficients appear to be too low, it is thought that the relation still holds. The user of refractories of this type is interested in what conductivity figures will mean to him in terms of fuel expenditure. The authors in this paper state—"of all the refractory materials available commercially, there is none which even approaches silicon carbide or carborundum in its ability to readily transmit heat and at the same time have mechanical strength and chemical inertness to resist the various destructive forces in modern industrial furnaces." There are at least two industrial furnaces in operation where strict comparisons may be made to show that fused alumina refractories do transmit heat as readily as silicon carbide. These two furnaces were at one time equipped with silicon carbide muffles and are now equipped with fused alumina muffles; in neither case has the fuel consumption increased; muffle temperatures are approximately the same for the same temperature in the ware chambers; and in both of these cases the muffles

[1] Howe and Phelps, *Jour. Amer. Ceram. Soc.*, **5** [7], 420 (1922).

were changed from silicon carbide to fused alumina refractories because the silicon carbide did not possess the necessary chemical inertness.

In the transfer of heat through a refractory in a commercial muffle furnace the coefficient of conductivity of the intervening refractory is not the only factor needing consideration, at least film coefficient and emission factor play a part in the drop in temperature between the source of heat and the product to be heated. The emission and film coefficients become of more importance relative to the conductivity coefficient when the refractory is thin. There is nothing in this paper to indicate that in these two factors silicon carbide differs from other refractories. In practical applications they apparently play an important part.

O. B. WESTMONT: The data recorded by Howe and Phelps[1] does indicate the possible effect of the diffusion of gases through the refractory wall upon the thermal conductivity. These data, however, show the changes in wall temperatures for quite a wide variation in pressure (+1.0 to −0.3 inch water). Our conductivity furnace was operated at such a very low pressure (0.05 inch water) that I believe the diffusion of gases would not affect our results appreciably.

Our values for the conductivity coefficient of carborundum and fire clay refractories do not differ greatly from the values recorded for similar refractories by most of the previous investigators.

Our average coefficients for fire clay and highly insulating materials are slightly lower than the average plotted by W. Trinks[2] for the same temperature range. The value for one commercial ceramically bonded carborundum refractory, Curve 5, Fig. 9 (p. 272), is approximately the same as that recorded by Wologdine for the same material. For the purer carborundum refractories the coefficients are, of course, considerably higher.

The statement that "thermal conductivity-temperature curves were not all linear functions" is correct as given. It *is* true that these curves for carborundum are straight lines, but with insulating materials they are not. It will be noted that only the conductivity-temperature curves for the recrystallized silicon carbide materials were drawn through two points. The conductivities for these refractories were practically constant for the temperatures shown (the gradient curves being constant through the major portion of the walls) so it was only necessary to indicate the limiting points in each case.

Our investigations show that the thermal conductivity for carborundum refractories now on the market is approximately four times that of fused alumina for the same temperature range.

F. H. NORTON: I think the authors of this paper should be complimented on the most complete work on thermal conductivity that has ever

[1] *Loc. cit.*

[2] "Industrial Furnaces," p. 67.

been done. We must realize that the measurement is one of the most difficult that there is.

On some conductivity tests that we have made on very dense brick we found the same condition of a falling off of the temperature at the cool face of the brick when using a sliding couple and we were a little suspicious of the result so we finally cemented in the face of the brick a very fine couple which should give the true temperature. In that case we found that the straight line of the higher temperature portion of the brick continued down to the outer temperature reading and the reading on the sliding couple was several hundred degrees low due to the conductivity of the couple wires and I think this is the case in these tests which would make the carborundum lower.

There is another thing that I wanted to bring out in the conductivity talk and that is that the conductivity seems to depend on the amount of heat carried through the walls. This is something that no one has noted before and if substantiated by further tests will prove a very important fact. However, it may be that insufficient guarding of the calorimeter in the thicker walls causes this phenomena. If there is a difference in the temperature between the center and outside of the calorimeter of only a few degrees it will introduce large errors in a wall of the thickness the authors used. We have found it necessary to use a 27-inch guard ring around a calorimeter only four inches in diameter to get a satisfactory guarding with high temperature with fairly good conducting brick.

W. A. KOEHLER: In regard to the thermal conductivity being complicated by diffusion of gases, I think the authors have taken reasonable caution to eliminate the diffusion of gases as completely as possible, although they may not have succeeded in doing so altogether. If we can eliminate diffusion and all other factors affecting the conductivity measurements, we obtain a true conductivity which is a fundamental physical constant. In addition, however, it would also be of value to know what the apparent conductivity would be in actual installations in which the diffusion of gases and all other factors are allowed to take their courses.

R. F. GELLER: What is the definition of conductivity? It seems to me that conductivity is an inherent quality of the material.

CHAIRMAN HARVEY: The pressure differs. In this particular case it is reduced to something like five-hundredths of an inch.

R. F. GELLER: The question has been asked: "What would have been the *conductivity* if the pressure had been greater?"

O. B. WESTMONT: It seems to me that the true thermal conductivity of a refractory is an inherent property of the material under certain conditions just as specific gravity, specific heat, etc. There are, however, so many possible variables entering in the determination of this coefficient that the apparent thermal conductivity may be quite different from the true co-

efficient. The most practical value then, would be that which is obtained under conditions which more closely approach those in commercial furnaces.

R. F. GELLER: My point is, that the abstract term *conductivity* is being used when "relative conductivity" or perhaps "actual heat conducted" is probably meant. This would, and should necessitate defining the conditions under which the trials were made.

O. B. WESTMONT: I believe we should define all the conditions whenever we determine our conductivity data, but I do not believe we can standardize them. If we secure data under one pressure we have no definite law, such as Boyle's law, for instance, by which we can calculate the coefficient at a different pressure. The same would apply for low temperature conductivity determinations.

In regard to the calorimeter guard ring referred to by Mr. Norton, we found that we had practically linear flow of heat through the test wall under our calorimeter with an 18-inch guard ring. The temperature gradients (Figs. 6, 7, and 8) are the average of the measurements in the three holes in the test wall. The curve for each gradient hole in a given wall did not coincide with the others in many cases due to slightly uneven heating on the fire side. The curves were, however, usually parallel showing that there was practically no lateral flow of heat.

A. S. WATTS[1] AND R. M. KING: Dr. Hartmann and Mr. Westmont emphasize the conclusion that the conductivity of carborundum increases with the quantity of heat actually transmitted. It appears to the writers that two conclusions can be drawn from this data, one being mentioned above and the other that Fourier's law does not hold under the conditions of the experiment.

It is our impression that Fourier's law is based on a condition of kinetic equilibrium within the material being tested. However, if we back up a wall of material of high thermal conductivity with a wall of material of low conductivity we cannot expect the outer wall to take away the heat as fast as the inner wall can deliver it, hence we would expect a damming up of heat at the joint and there would soon be developed a zone where the heat is in static equilibrium or rather what we might call a reservoir where heat is flowing out as fast as it is flowing in. This being the case the conditions of Fourier's law have been changed and hence we feel that we cannot agree with the authors' conclusion. We would rather conclude that Fourier's law does not apply in this particular case.

It is unfortunate that Dr. Hartmann and Mr. Westmont did not obtain more data on carborundum walls of varying thickness. We would like to compare the data obtained on a 9-inch wall of a particular grade with

[1] Dept. of Ceramics, O. S. U., Columbus, Ohio.

that obtained on a $4^1/_2$-inch wall of the same material, but this is not possible with the data available. However, we note that a 9-inch wall of Carbo No. 1A allows the passage of 1.415 C.G.S. units of heat with the resulting conductivity calculated as .0403 C.G.S. units, and a $4^1/_2$-inch wall of Carbo No. 1B conducts 1.801 units at the rate of .0430 units, and a $4^1/_2$-inch wall of Carbo No. 1C conducts 2.314 units at a rate of .0542 units. Following the conclusion of the paper we could say that this increase in conductivity is due only to the increased heat energy transmitted. This is to be expected if we accept Fourier's law. But we would ask why the increased transmission of heat? We can account for at least a part of this by the higher silicon carbide content in 1B and the increased density in 1C. However, when we note a decrease in heat flow in the composite walls we explain this by saying that the fire clay will not transmit the heat as rapidly as will the carborundum.

We would like to call attention to the fact that Carbo No. 4 conducts less heat than does Carbo No. 5 and yet No. 4 has a conductivity of .0204 and No. 5 a conductivity of .0178. Again No. 5 uninsulated conducts four and one-half times as much heat as when insulated but the conductivity is the same in both cases.

If the authors' conclusions are correct regarding carborundum brick, *i. e.*, that increased transmission of heat increases conductivity, why would not any other refractory when backed up with a good insulator show an increase in conductivity with increased quantity of heat transmitted. A fire clay brick backed up with a kieselguhr brick, should display the same properties as the carborundum backed up with fire clay brick. Dr. Hartmann and Mr. Westmont have not presented any data to show that this is not true.

M. L. HARTMANN AND O. B. WESTMONT:[1] Replying to the third paragraph of the discussion by Watts and King, further accurate conductivity data are always desired, and in this case may be forthcoming at a later date. As noted in the paper, the increased heat transmission in the wall 1C is partly explained by the diffusion of gases from the furnace, which experimental defect was corrected in the other experiments.

In comparing the conductivities of two similar walls both the heat flow and temperature gradients of each must be taken into consideration. The thermal conductivity is, obviously, not directly proportional to the heat flow.

With those refractories having a high percentage of fire clay bond, the change in conductivity with heat flow in insulated walls becomes less pronounced. The limit of this change is in the 100% fire clay brick in which the conductivity is apparently independent of the heat flow.

[1] Written reply to Watts and King discussion.

M. L. HARTMANN AND O. B. WESTMONT:[1] Mr. Hudson's skepticism as to the accuracy of our data because they do not conform to other published information on the thermal conductivity of carborundum refractories seems to us to be hardly justified. Examination of the literature discloses the following:

	Firing temp., °C	Composition	Temp., °C	Thermal condy., C. G. S. units
Wologdine:[2]	1300	87% SiC	300–650	0.019
	1300	87% SiC	230–440	0.027
	1300	75% SiC	420–1000	0.015
Linbarger:[3]	1350	10% Clay Bond	0–1000	0.024
Moores:[4]	..	.....	900	0.0235
Beecher (Norton Co.):[5]	..	10% Clay Bond	650–1250	0.00982

Even with the considerable variation in composition and burning conditions, there appears to be fairly good agreement as to the *order of magnitude* of the coefficient, with the exception of the last reference.

We have investigated to some extent the surface film and the emissivity factors of carborundum and fire clay refractories. The surface temperature drop due to the gas film resistance under our test conditions was not appreciably different in carborundum (80°C) from that in the fire clay (95°C). The emissivity of carborundum (page 279) was found to be nearly double that of fire clay.

There appears to be scanty experimental evidence to show so small a difference as 15% between the thermal conductivities of silicon carbide and fused alumina refractories. The results of Watts and King[6] show that the conductivity of "Carbofrax B" is 3.39 times that of "Alundum" at approximately 1000°C. The value recorded by Beecher for "Alundum" is .00833 C.G.S. units for temperatures ranging from 650–1250°C. Our values for two kinds of "carbofrax" refractories for the same temperature range (Curves 4 and 5, Fig. 9) are 2.86 and 4.19 times this value for "Alundum."

The extended use of carborundum refractories for heat transmission in the past few years seems to indicate conclusively the composite opinions of furnace users as to the superior property of carborundum to conduct heat over that of any other refractory material. There are conditions in-

[1] Written reply to C. J. Hudson's discussion.

[2] Wologdine, *Electrochem. and Met. Ind.*, **7**, 383 (1909).

[3] Linbarger, *Chem. and Met. Eng.*, **19**, 489 (1918).

[4] K. T. Moores, Thesis, Mass. Institute of Technology.

[5] Beecher, *Jour. Amer. Ceram. Soc.*, **7** [1], 19 (1924).

[6] Watts and King, *Jour. Amer. Ceram. Soc.*, **6** [10], 1075 (1923).

volving chemical activity under which carborundum does not have sufficient life for economical operation, but as a good transmitter of heat, it is not approached by any other refractory material.

P. NICHOLLS:[1] The conclusion arrived at by the authors that the thermal conductivity of a material, or for carborundum at least, varies at a given temperature with the rate of heat flow is so revolutionary that it calls for immediate proof or rebuttal by further tests introducing different test conditions, or eliminating possible sources of error. The fundamental principle of all heat conduction is based on the independence of conductivity and the rate of flow; proof to the contrary would require its entire revision and some new concept of the mechanism of conduction. Moreover, the tests show that the variation is not small but (see Fig. 13) at 1350°C is several hundred per cent.

That the thermal conductivity may and does vary greatly with temperature is of course true, but even then one would expect to find changes in some other physical characteristics of the material if the variation were abnormal, such as from fusing or melting.

The authors suggest that since the material is cellular the conductivity variation with rate of flow may be due to the radiation factor of the transmission across the small air spaces. That such an action would cause the conductivity to vary with the rate of flow is correct, and if the amount were appreciable, the normal heat conduction mathematics could not be applied. The magnitude of this action can be estimated if definite structural conditions are assumed, but the mathematical expressions become rather complicated. However, it is not difficult to show that it is small even for a structure in which all the transfer is by repeated radiations, and none by conduction of the air between the successive layers of material. Imagine a slab made up of very thin parallel laminae with no thermal resistance. If heat flows through this by radiating from one surface to another, it can be shown that the equivalent conductance coefficient, C, between two surfaces, one being at a temperature T degrees absolute temperature, would be of the form $C = a(T^3 \pm T(\Delta T)^2)$, where a is a constant, and ΔT the small difference in temperature between the faces of the two laminae.

It is evident that the value of C would vary rapidly with the temperature T, and since the ΔT would be proportional to the rate of heat flow, C would depend on that also. Since there are many laminae, $T(\Delta T)^2$ would always be small compared with T^3. Arithmetical illustrations could be given but the above shows that the effect of the rate of heat flow would be small in itself and moreover that it would be entirely masked by the rapidly increasing temperature coefficient of the conductance, varying as T^3.

[1] Heat Transmission Engineer, U. S. Bureau of Mines, Pittsburgh, Pa. Recd. March 26, 1925.

In a cellular material the radiation factor part of the heat transfer will itself be small compared with the conduction factor, so that the ΔT effect will become insignificant.

Since there is apparently no other action that might account for the results obtained, it is more reasonable to look for test errors. Assuming the computations are correctly made, the most probable source of error would be the temperature measurements through the refractory, as all computations for conductivity depend on the shape of these curves. The errors in measuring the heat absorbed by the calorimeter should not be large and would only slightly affect the values here discussed. The measuring of temperatures by means of holes drilled in the direction of the heat flow is wrong in principle, has often been found to give inaccurate results, and has been used seldom. The use of the wires to give three sets of couples would add to the capacity to carry away heat from the couple points and lower their temperatures, and the passing of their wires through the metal of the calorimeter may possibly assist in the cooling.

An opposite action may have occurred due to hot gases passing through the thin layer of material at the hot end of the hole, or the two actions may have been combined.

Whatever may have been the cause, the temperature curves themselves, Figs. 6, 7, and 8, show very unlikely tendencies. Figs. 7 and 8 show a considerable and extended curvature when they pass from one material to another. The correct values would give sharply defined changes of slope, with some indication of the joint resistance. The humps in the curves of Fig. 6 indicate a large and rapidly accomplished change in conductivity at a comparatively low temperature which would have to be accounted for. Curve 1 of Fig. 8 shows an even larger change at a still lower temperature.

If these curvatures are not justifiable, then the slopes of some other part of the curves must be changed to take them out, and such alterations might do away with the differences due to rate of flow.

The above are of course only suggestions and surmises, and one would never deny the possibility of some previously unknown action being discovered. It does seem improbable, however, that such large departures from normal actions should be confined to one material, without some indication of it being previously noted in others.

The summation of these variations with heat flow are shown in Fig. 13; from these it is to be concluded that with small rates of heat flow the conductivity approaches zero, that is, the material tends to become a perfect heat insulator. In heating up a material the rates of flow must be small before they can become large, and therefore the logical conclusion would be that, since they could never start to transmit heat, they would never heat up, or would do so very slowly if the conductivity tends to approach, but does not reach zero.

M. L. HARTMANN AND O. B. WESTMONT:[1] In reply to Mr. Nicholls' discussion, further work is in progress to confirm our conclusions that the apparent thermal conductivity of refractories at high temperatures does change with heat flow. There exist so very few reliable thermal conductivity data on walls transmitting varying amounts of energy (especially at high temperature) that no one is warranted in categorically denying the possibility of a change of apparent thermal conductivity with variations in heat flow.

Before starting this investigation we made a thorough study of the possible methods of measuring the conductivity coefficient at high temperatures and concluded that the one employed by Dudley was the most accurate and at the same time most practical for use under actual operating conditions. A casual examination of the discordance of the results of previous investigations is sufficient to justify the adoption of this method in preference to those used by the earlier investigators.

The use of thermocouples for measuring the temperature gradients is undoubtedly the most accurate method. It is true that these couples do conduct some heat, but this does not affect the results appreciably. Regardless of the position of the wires relative to the direction of heat flow in the test wall, it is evident that practically the same amount of heat would be carried away by conduction through the couple wires.

The curvatures in Figs. 6, 7, and 8 at the wall joints and near the calorimeter are due to inaccuracies in measuring surface temperatures at joints. So many factors, such as surface irregularities, local convection currents, etc., affect the temperatures at joints and surfaces that we expected "unlikely tendencies" and consequently did not use the data in our calculations on furnace walls. Because there are recognized inaccuracies in these joint measurements, there is no justification in assuming a similar error in the measurements in the major portion of the test wall.

In using either fixed or movable couples for measuring the temperature gradient there is a certain temperature differential between the interior of the solid brick and the junction of the thermocouple, but this differential is constant. Since it is constant at different positions the slope of the gradient curve is realized and we have an accurate basis for calculating the thermal conductivity. In using fixed couples for measuring gradients, either a prohibitive number of couples would be required or assumptions have to be made that the gradient is uniform between the couple junctions.

The portion of the curves near zero in Fig. 13 indicate the trend of the thermal conductivity-heat flow curves. These curves, however, should not have been drawn through the zero point, and may be accurate only so far as the last indicated observation.

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[1] Recd. April 7, 1925.

QUANTITATIVE DETERMINATION OF THE DEVELOPMENT OF MULLITE IN FIRED CLAYS BY AN X-RAY METHOD[1]

By Louis Navias

ABSTRACT

Firing clays alone or with fluxes to high temperatures results in the formation of mullite crystals in a highly siliceous vitreous mass. Quantitatively, the extent to which mullite in clays is developed by firing to cone 10 has been determined for Ivory Fat English ball clay, Great Beam ball clay, Jernigan Tennessee ball clay, M. & M. English ball clay and A-1 English china clay.

The method consisted in procuring X-ray patterns by the powder method of the clays fired with feldspar as a flux, using mullite as a reference material. The intensities of the lines in these photographic films were then compared with the intensities of lines obtained from a series of mullite and feldspar mixtures, fired to vitrify the flux.

The results given in Table II indicate that each clay develops the maximum quantity of mullite in crystalline form, which the chemical composition of the clay allows.

Introduction

At the present time the fact is fairly well established that heating a clay to high temperatures results in the formation of the crystalline compound, *mullite*,[2] the aluminum silicate, $3Al_2O_3.2SiO_2$, which in former days was erroneously considered and recorded as sillimanite. Mellor and Holdcroft[3] maintained that the formation of sillimanite in kaolinite when heated over 1200° was due to the recombination of the free alumina and free silica formed at about 500°. Vernadsky[4], however, believes that a kaolin at 420–530° forms an anhydride $Al_2Si_2O_7$, leverrierite. After polymorphic changes at higher temperatures the nucleus at 930–950° breaks up during an exothermic reaction setting free SiO_2. It is not the province of this note to deliberate on these different views other than to indicate that at these higher temperatures a crystalline aluminum silicate is formed. With our present knowledge of the subject it is safe to assume that the compound is *mullite*.

More recently Kraner[5] has followed the development of mullite in fired clays by means of the changes in refractive index of the aggregates of material resulting from heating the clays to successive temperatures. The keynote to his paper is contained in the sentence "Because we cannot see crystals of sillimanite in the (clay) mass is not sufficient cause to state that submicroscopic or colloidal crystalline sillimanite is not present." His conclusions in part are:

"Sillimanite development seems to be a gradual rather than a sudden one.

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[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb. 1925. (White Wares Division.)

[2] N. L. Bowen and J. W. Greig, *Jour. Amer. Ceram. Soc.*, **7** [4], 238–54 (1924).

[3] J. W. Mellor and A. D. Holdcroft, *Trans. Ceram. Soc.* (Eng.), **10**, 94–120 (1910–11).

[4] W. J. Vernadsky, *Trans. Ceram. Soc.* (Eng.), **22**, 398–401 (1922–23).

[5] Hobart M. Kraner, *Jour. Amer. Ceram. Soc.*, **7** [10], 726–34 (1924).

With progressive heating it probably begins as soon as the clay molecule is dehydrated."

"Sillimanite development apparently takes place as abundantly in clays which do not contain impurities as in those in which early fluidity operates to promote the size of crystals."

Apart from the theoretical interest in the subject of the development of mullite in clays, or in compositions which contain clays, there is also the practical aspect which would benefit from a solution of the problem of the extent to which mullite is developed in fired clays. Searle[1] states that "Ideal porcelain should consist of a mixture corresponding to the formula $Al_2O_3.SiO_2$ (sillimanite) and a fusible glass which binds the other particles firmly together. When materials capable of producing such a mixture are heated to a sufficiently high temperature they will form a felted mass of sillimanite needles bonded with a glass cement." Aside from the plasticity necessary for working a porcelain composition it is important to know whether a ball clay contributes as much as a kaolin to the fired product with regard to the development of mullite as interlocking crystals, and whether individual clays of any type may be classified according to this property.

As will be shown later, resulting from the molecular transformations which a clay undergoes in firing there is left in the magma a superabundance of (free) silica. And there is some justification in Reichau's[2] remark that "silica in a (porcelain) body does not aid, but actually prevents the growth of sillimanite.....," in criticizing Searle's[3] statement "the chief purpose of the clay and some of the free silica in all porcelain is to produce the felted mass of sillimanite crystals, which form the skeleton of the finished ware and to provide a reinforcement which will prevent undue distortion of the ware."

Our purpose was therefore to obtain some quantitative evidence of the extent to which mullite is formed in fired clays, and especially in combination with a flux like feldspar, somewhat simulating conditions obtained in practice. The method was that of making direct comparisons between a set of standards containing known percentages of mullite and fired clays containing unknown quantities of mullite, by means of the intensities of the mullite pattern obtained on photographic films by exposing the materials to X-rays.

Historically it is interesting to note Zoellner's[4] results. By heating clays to high temperatures and then disintegrating the products in hydrofluoric acid, he obtained a residue of mullite crystals. He concluded that cone 10 (ca 1300°) had to be reached before the mullite could be obtained,

[1] A. B. Searle, "The Chemistry and Physics of Clays." London, 1914, p. 375.
[2] K. H. Reichau, *Keram. Runds.*, **38**, 1–26 (1924).
[3] A. B. Searle, *loc. cit.*, p. 377.
[4] Zoellner, *Brit. Clay Worker*, **22**, 40 (1913).

and that the plastic clays gave only 3–5% mullite whereas the lean clays (kaolins) gave 25% under similar conditions of firing.

Materials Experimented With

Mullite

Mullite was prepared in quantity by fusing pure silica and alumina in the correct proportions to give $3Al_2O_3.2SiO_2$. The raw materials were well mixed and placed in a flat rectangular sagger. An arc was struck between two large graphite electrodes imbedded in the mixture, whereby the mass at the center was fused. The electrodes were moved apart until the resistance to the current became too great to maintain the arc. After cooling, the fusion was removed. It consisted of a large cake of crystalline material surrounded by unfused and partially fused batch. The latter was removed by grinding, yielding a mass of mullite crystals, some over an inch in length. Microscopic examination of a thin section, and of the powder of the inner mass revealed the needle structure and optical properties of mullite. After a few trials, products free from glass were easily obtained.

Clays

The clays experimented with are given in Table I, with chemical analyses determined on three of the samples. The analysis of the M. and M. ball clay is an approximate one supplied to us by the producers of the clay. The chemical analysis of the feldspar is also included.

TABLE I

CHEMICAL ANALYSES OF CLAYS AND FELDSPAR

	Jernigan Tenn. ball clay	Ivory fat Eng. ball clay	M. and M. Eng. ball clay	A-1 Eng. china clay	Derry feldspar
SiO_2	50.80%	54.62	51.55	42.10	63.82
Al_2O_3	27.75	25.32	30.70	38.83	20.50
Fe_2O_3	1.95	1.62	2.33	0.81	..
CaO	0.40	0.62	0.47	0.56	0.50
MgO	0.88	0.95	0.20	0.66	0.61
K_2O	n.d.	n.d.	1.40	n.d.	11.05
Na_2O	n.d.	n.d.		n.d.	3.59
Ign. loss	17.80	16.20	13.37	17.28	0.40
	99.58	99.33	100.00	100.24	100.47
Mol. ratio $\frac{SiO_2}{Al_2O_3}$	3.11	3.66	2.86	1.84	

Clay Series

The clays were fired to cone $9\frac{1}{2}$ in a commercial kiln, and pulverized for X-ray examination.

Clay-Feldspar Series

Each of the clays in the raw state was mixed with feldspar in the proportions of 60 parts clay and 40 parts feldspar, made into cones and fired in a commercial kiln to cone $10\frac{1}{2}$. A pulverized portion of every fusion was taken for the comparisons. The feldspar and clay in each instance had vitrified,

and microscopically the only crystalline materials present were mullite crystals developed from the clays during the heating and cooling, and the quartz fragments introduced as an impurity.

Mullite-Feldspar Series Mullite, finely ground was mixed with feldspar in proportions of 0, 5, 10, 15....50% and made into cones which were fired to cone 9½. The feldspar fused to a glass and did not attack the mullite appreciably. The resulting fired cones were ground to powders to form a series of mullite standards from 0 to 50% with feldspar glass as the diluent. The quartz content of the feldspar was less than 1%.

Experimental Procedure

Clay Series One-half of a fine capillary glass tube having a partition at the center was filled with the powdered fired clay mixed with an equal volume of flour, and the other half with powdered mullite mixed with an equal volume of flour. The flour merely separates the particles and dilutes the material. Each tube, with a photographic negative held in an arc of a circle behind it, was then exposed to X-rays[1] for 165 hours. In this manner a photographic film was obtained on which the lines on the upper half represent the crystalline materials in the clay, whereas the lines in the lower half are representative of the reference substance, *mullite*.

In all cases the fired clays gave intense X-ray patterns identical with that of mullite, indicating that they all contained large quantities of mullite. However, the lines were too intense to enable a comparison to be made of the relative contents of mullite in the different clays.

Clay-Feldspar Series By a similar process, X-ray patterns were obtained of the clay-feldspar series, with the mullite as the reference material in each case, each sample having been diluted with flour. Again the only pattern obtained for each of the clays was that corresponding to the mullite. Under the conditions of exposure to X-ray there was no evidence of any quartz lines on the films, although quartz was known to be present in the ball clays.

Mullite-Feldspar Series Each of the mullite-feldspar series containing from 0 to 50% mullite in increments of 5% was treated as an unknown. The reference substance mullite was mixed with flour. Every photographic film thus contained in the upper part the lines due to the mullite diluted with feldspar, and in the lower part the lines of the pure mullite. The intensities of the more prominent lines of the pattern increase as the percentage of mullite in the series becomes greater, and there is no difficulty in detecting differences of in-

[1] For details and principle of power method see article in *Gen. Elec. Rev.*, 1925, by W. P. Davey.

tensity between them. The film of the 100% feldspar was blank except for a few extremely faint lines corresponding to the small quantity of quartz present.

Quantitative Determination of Mullite Content in Fired Clays

A direct comparison was then made between the ratio of intensities of the two sets of lines on a clay-feldspar film with the ratio of intensities of the two sets of lines on each of the films of the mullite-feldspar series. Where the relative intensity of the unknown lay clearly between two standards an average value was taken. For every match of intensities a simple calculation gave the percentage of mullite contained in the respective clay. The quantity of mullite developed in each fired clay calculated as a percentage of the raw clay is listed in Table II under the heading "Mullite determined."

At first appearance the percentage quantities seem rather large. It is then interesting to compare the percentages of mullite thus found in the fired clays with the maximum percentages of mullite which can theoretically be found from the alumina and silica contents of the clays. The calculated values are given in the column headed "Mullite calculated" and are based on the chemical analyses of the raw clays.

Within the estimated experimental error of about ±5% the calculated and determined values agree surprisingly well and they lead to the interpretation that the clays experimented with whether ball clay or china clay when fired to cone 10 (about 1300°) develop in a crystalline form the maximum quantity of mullite which their alumina and silica contents will allow. Notice should be taken of the fact that two of the ball clays developed only half of the mullite accredited to the china clay.

TABLE II

MULLITE DEVELOPED IN CLAYS FIRED TO CONE 10

	Molecular proportions		Mullite calculated	Mullite determined
	Al_2O_3	SiO_2		
Ivory Fat Eng. ball clay	3.00	10.98	35%	33%
Great Beam ball clay	..	..	..	33
Jernigan Tenn. ball clay	3.00	9.33	38	40
M. and M. Eng. ball clay	3.00	8.58	43	50
A-1 Eng. china clay	3.00	5.52	54	60
Mullite	3.00	2.00	..	..

The values are given as weight percentages of the respective raw clays.

To show the great excess of silica that must necessarily remain in the magma the silica-alumina ratios of the clays have been calculated on a basis of $3Al_2O_3$ to have a common term with the mullite formula. In the china clay the excess of silica is about 4 moles, whereas in the ball clays the ex-

cess silica varies roughly between 6 and 9 moles. With so large an excess of silica present, it is to be expected that at higher temperatures and in the presence of fluxes, partial solution of the mullite will take place, and as the excess of silica becomes greater the quantity of mullite remaining in the cooled magma will be correspondingly decreased. This condition will become more pronounced when silica is added to the composition, as for example, quartz or flint in porcelain. The development of a crystalline phase is intimately connected with the viscosity of the magma and the presence of large quantities of silica in the mixture, will tend to inhibit the crystallization of mullite on account of the increasing viscosity as the silica dissolves in the melt.

By a rational analysis the Ivory Fat English ball clay was found to contain 15% free quartz, leaving 36% SiO_2 combined with 28% Al_2O_3, thus giving a silica-alumina molecular ratio of 2.2. Old analyses gave, on discounting the free silica, molecular ratios of 2.1 for the Ivory Fat English ball clay, and 2.0 for the M. and M. English ball clay. The A-1 English china clay on the other hand was practically free from quartz and had a molecular ratio of roughly 1.8. A review of the literature shows similar proportions for washed clays and for clays whose chemical analyses specifically state the free silica content. In the former the free silica has been removed, while in the latter allowance can be made for the free silica.

The TiO_2 and Fe_2O_3 content of a clay is another factor which cannot be overlooked in a study of the subject. Bowen, Greig and Zies,[1] have shown that the inclusion of these oxides in the composition of the mullite affects its optical properties. It would seem plausible then to assume that these oxides combine with silica and add their quota to the total mullite, crystallizing out.

With the extreme variations of the silica-alumina molecular proportions of 1.8 and 2.2 calculation shows that a clay with the smaller ratio can develop 68% mullite, whereas the clay with the larger ratio can develop 61%, these percentage values being based on the alumina and silica contents only, which will apply to fired clays that contain no other oxides. The difference of 7% mullite obtained between these wide limits is small. While no generalizations on this point are intended it is striking how closely the argillaceous substance in each of the clays approaches in composition the theoretical molecular proportions of kaolinite, and how small an effect the above-mentioned variations have upon the maximum development of mullite in the respective clays.

Conclusions

1. By comparing the X-ray patterns obtained from clays, fired either alone or with feldspar as a flux, with the X-ray pattern of mullite it is found

[1] Bowen, Greig and Zies, *Jour. Wash. Acad. Sci.*, **14**, 183–191 (1924).

that the crystalline development in the fired clays is similar to the crystalline compound mullite.

2. The extent to which the mullite is developed in the clays fired to cone 10 has been determined quantitatively, the values being 33, 33, 40 and 50% for the ball clays and 60% for a china clay, calculated as weight percentages of the raw clays.

3. By calculating the theoretical quantity of mullite which each clay can develop from its alumina and silica content, and comparing these calculated values with the quantitatively determined values of mullite, it is shown that within the experimental error each clay, whether a ball clay or china clay develops the maximum quantity of mullite, theoretically possible.

4. From the limited number of clays experimented with it appears that there is only a small difference, if any, between the clay substances of the china clay and the ball clays, the criterion being the development of mullite on firing.

Acknowledgments

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A METHOD OF CONTROL OF ENAMEL FOR DIPPING FLAT WARE[1]

By R. R. Fusselbaugh and B. T. Sweely

ABSTRACT

Development of varying specific gravity to control the dipping consistency of ground coat. The necessity of constant mill load and milling. Most efficient milling reached when 1/2% of glass was retained on 150-mesh screen.

The object of the tests is to develop a practical method of control of the dipping operation on flat ware. Such a method must be one which can be readily introduced into the shop for quick and practical results. As the ground coat enamel is the first as well as the most important coat to be applied to the steel, experiments were made with this enamel and with favorable results.

Standards, whereby enamel shops may govern their various products, operations, etc., have long been sought by the enameler and it is quite possible that the experiments and the results thereof described in this paper may be beneficial.

In attacking the problem of control of our dipping and draining, our object was to secure a method of controlling the enamel at the dipping tubs, whereby a uniform thickness of coating of enamel could be secured day after day, and a method of control of the milling operation which would deliver a uniform enamel to the dipping tubs.

Since heavier or thinner enamel is secured by adding at the tubs either heavier enamel or water, we decided it would be feasible to control the dipping consistency by specific gravity determinations or weights per unit volume.

Throughout this investigation a standard mill charge was used in each instance mentioned and consisted of the following:

1000 lbs ground coat frit	10 lbs. borax
100 lbs. ground flint	2 lbs. soda ash
60 lbs. clay	water

To vary the specific gravity water was added to our standard slip as it came from the mill, and weights taken of a constant volume for variations

Table I

Number	Pounds per liter	Appearance after firing
1	3.98	Too thick
2	3.89	Too thick
3	3.85	Good
4	3.79	Thin
5	3.75	Thin. Started to fire out
6	3.71	Fired out

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb., 1925. (Enamel Division.)

in the water content; trials were then dipped in the various samples and fired with the results as given in Table I.

The results of these trials indicated that the enamel used was milled finer than necessary. Another mill was therefore started and samples drawn from the mill at various times. Screen analyses of these samples were made with the following results.

TABLE II

PER CENT OF GLASS RETAINED ON SCREENS

Milling time, hrs.	Mesh 150	120	100	80	60
12	14.56	9.88	5.36	0.90	0.18
14	10.77	5.60	1.79	.26	.07
16	7.04	4.03	.86	.14	.02
18	4.98	3.01	.64	.12	.01
20	3.16	1.73	.25	.02	...
22	2.02	.87	.13	.01	...
24	1.39	.68	.07	...	...
26	.97	.42	.04	...	...
28	.70	.26	.02	...	...
30	.47	.16	.06	...	...
32	.29	.12	.01	...	...
34	.19	.07	.01	...	...
36	.12	.04	...	...	...

A sample of this slip was dried and found to contain 25.23% water.

Samples from the above milling were made up to a weight of 3.85 lbs. per liter, trials dipped in them and fired with the results shown in Table III.

TABLE III

Milling time, hrs.	% loss by drying	Lbs. per liter	Appearance after firing
16	28.64	3.85	Fair. A little too thin
20	28.97	3.85	Good. A little thin
24	29.17	3.85	Good. Correct thickness
30	29.25	3.85	Fair. A little thick
36	28.91	3.85	Poor. Too thick

Since we had secured the best results with our standard mill charge when run from 20 to 24 hours, and had found it necessary to add a certain amount of water to this enamel in order to secure the weight of 3.85 pounds

TABLE IV

PER CENT OF GLASS RETAINED ON SCREENS

Milling time, hrs.	Mesh 150	120	100	80	60
14	3.59	1.63	0.28	0.06	0.03
16	2.19	.83	.13	.03	.01
18	1.19	.47	.07	.01	...
20	.78	.26	.02	.01	...
22	.42	.13	.02	...	...
24	.28	.07	.01	...	...

per liter, we decided to run another mill trial in which the necessary water was added to our standard mill charge in order to bring this enamel to an approximate weight of 3.85 pounds per liter. The results of the screen analyses of this trial were as shown in Table IV.

Trials were dipped in the samples drawn from this mill at the various times as shown in Table IV, all of which had a specific gravity of approximately 3.83 pounds per liter with the results as shown below (Table V).

TABLE V

Hours, milling	Appearance of fired trials
14	None made—enamel too thin
16	Fair
18	Very good
20	Good
22	Good—thick
24	Good—thick

The degree of fineness of the frit in suspension has a decided influence on the thickness of the enamel which will adhere to the ware in draining when all other factors are constant.

Separate mills of enamel gave like results when the per cent of glass retained on the same mesh screen was the same, or nearly so, for the separate millings at the same specific gravity.

Variation of the specific gravity of a particular slip varies the thickness of the enamel coating which will adhere to the ware.

It will be noted from a study of Tables II and IV that approximately the same degree of fineness was secured in 18 hours with a water content of about 29% as was secured in 24 hours with a water content of 25%. Further study of these tables indicate a rather sharp decrease in the grinding action of the mill after a certain degree of fineness is attained. This point is more clearly shown by the accompanying curves (Fig. 1).

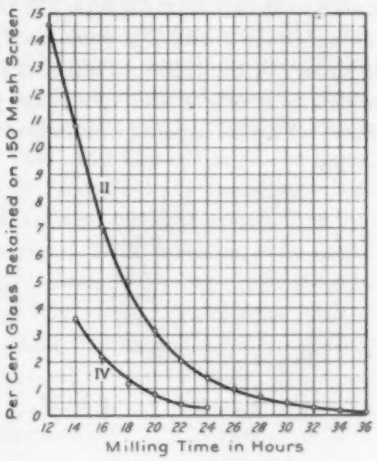

FIG. 1.

In applying the above data to our shop practice we have standardized oug mill charge and milling with satisfactory results. All water, glass, clay, etc., introduced in the mill charge is accurately weighed and our actual milling put under control by use of a revolution counter. The degree of fineness is frequently checked by screen analyses. The specific

gravity of the enamel is daily brought to the standard set before any ware is dipped and after every addition of enamel to the tubs, with the result that we have almost eliminated our difficulties due to uneven dipping.

In setting the enamel the foreman is provided with a narrow mouthed glass stoppered bottle (quart size). Each bottle is calibrated according to its volume, as compared to one liter. The foreman does the weighing and knows that for the particular bottle which he is using, the bottle filled with the slip he is going to use must weigh just so much for good dipping. He adds either water or heavier slip in order to get the slip to the required weight.

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BALTIMORE, MD.

GLAZES COLORED BY MOLYBDENUM[1]

BY WAYNE E. BARRETT

ABSTRACT

Molybdenum used as a colorant for glazes has a strong coloring power even though used in small percentages, affecting the glaze as R_2O_3. Both a bright yellow and a bluish green were secured.

Molybdenum has a strong coloring power. The oxide was mixed in the porcelain batches. These turned a deep blue on drying in the plaster molds. When fired to cone 12, the samples had a bluish green color, and though both 1 and 2% were used, there was no apparent difference in the intensity of the color. Different percentages of oxide of molybdenum were added to a bright and to a matt glaze without grinding. The test pieces were white hexagonal underfired tile. The color secured was a bright yellow.

BODY

Tenn. ball clay	38%	
Feldspar	29.5%	
Flint	32.2%	
MoO_3	2 and 3%	Cone 12

GLAZES

Bright			
0.10 CaO			
0.20 K_2O	0.25 Al_2O_3	1.6 SiO_2	Cone 02
0.70 PbO			
Matt	2, 4, 6, 10% of MoO_3 added to each		
0.45 CaO			
0.20 K_2O	0.29 Al_2O_3	1.87 SiO_2	Cone 2
0.35 PbO			

ADEL CLAY PRODUCTS COMPANY
ADEL, IOWA

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Columbus, Ohio, Feb., 1925. (Art Division.)

THE ACTION OF ARSENIC COMPOUNDS ON TANK BLOCK[1]

By D. J. McSwiney

ABSTRACT

Comparison of the average life of soda lime glass tanks melting green glass and those melting flint glass in which selenium is used as a decolorizer, where the same or similar batch and operating conditions obtain in both cases, shows that the life of the selenium flint tanks is invariably much shorter than that of the green tanks. This shortening of tank life is independent of the amount of selenium used or the form in which it is used but varies with the amount of arsenic used in conjunction with the selenium.

A much discussed point in connection with the use of selenium as a decolorizer for soda lime flint glass is the effect of the decolorizer on the life of the tank in which it is used. Most flint glass manufacturers claim that by the use of selenium the life of their tanks is greatly reduced. In answer to this the counter claim is made[2] that decreased tank life through the use of selenium is only apparent; that the decreased life is actually due to the increased pull exerted upon the tanks through the introduction of high speed glass forming machinery during the past decade, and through the higher temperatures and more fusible and corrosive glasses used to meet this increased pull.

This may possibly be true of glass tanks in general, but it is none the less true that the life of selenium flint tanks has been abnormally shortened, as is evidenced by the fact that in any factory where green and flint soda lime glasses are made and in which the flint glass is decolorized by the use of selenium and arsenic, the life of the green tanks is, on an average, from 50 to 100% greater than that of the flint tanks, although, the same block is used in the two tanks; they are warmed in the same way, the same temperatures are used, the same average pull, and the batch is the same with the exception of the selenium and arsenic used for decolorization. Moreover, in those cases where the introduction of high speed forming machinery antedated the change from manganese to selenium, the same condition holds—the average life of the manganese tanks was much greater than the life of selenium tanks operated under similar conditions with a batch which was probably more corrosive than the present selenium batch in which little or no niter is used.

The Case of Selenium

The type of attack of the present selenium batch differs from that of the old manganese batch. The action of the latter was exerted on the block in the vicinity of the dog-house and on the rear walls; while the action of the selenium batch appears to be an accentuation of the erosive action of

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb., 1925. (Glass Division.)

[2] R. R. Shively, *Bull. Amer. Ceram. Soc.*, **3** [9], 333 (1924).

the glass, being exerted largely on the points where the rate of glass flow is greatest, that is on the throat and the block in the working end near the troughs. The blame for this increased action has always been put on the selenium as this was the only new glass material introduced, and this despite the fact that there was no particular evidence that selenium should have such a corroding action. The amount of selenium introduced into the glass for decolorization never exceeded 0.003%; in cases, such as selenium ruby, where four hundred times this amount of selenium is used there is no evidence of increased block or pot attack; the degree of corrosion does not appear to be influenced by the form in which the selenium is introduced and is independent of the amount of selenium used for decolorization.

I have long felt that the corrosion should be ascribed, not to the presence of selenium in the glass, but to the use of the arsenic oxide, and an investigation of the problem from this viewpoint affirms this assumption.

Corrosion in Proportion to Arsenic Content

While the increase in corrosion of flint tanks over that of green tanks in the same factory and operated under the same conditions does not vary as the amount of selenium used for decolorization, it does vary as the amount of arsenic so used. The selenium tanks which show the greatest average decrease in life are always those in which the greatest amount of arsenic is used. Those flint tanks using selenium as a decolorizer but which do not use arsenic in conjunction with it, show no decrease in average life over similarly operated manganese or green tanks, except where such a decrease can be easily attributed to a radical change in batch or operating conditions. Some flint tanks using selenium without arsenic show an apparent average increase in tank life. In the case of one glass manufacturer, when selenium was first used in his batch as a decolorizer it was used without arsenic, and for a period of three years following such introduction the average life of his flint tanks was about the same as his green tanks operated under the same conditions. To eliminate the brown selenium color four pounds of arsenic per ton of sand was then used in the batch and during a period of almost three years the life of his flint tanks decreased to an average of about eight months compared with an average of twelve months for the green tanks over the same period.

The effect of the arsenic on the block is not limited to flint tanks but can be seen in green tanks using arsenic. For example, a green glass manufacturer using a high grade sand changed to a local sand containing titanium, and to eliminate the off-color caused by the titanium, he used five pounds of arsenic per ton of sand in his batch. The average life of his tanks dropped from fourteen months without arsenic to about six and one-half months with arsenic. As the cost of the arsenic offset the decreased

cost of the local sand he returned to the use of the former sand and his tank life increased to about eleven months.

The use of arsenic in glass batches is not new, as it has long been used in glass as a clarifying agent, especially in colored glasses. However, its use in such cases was more or less isolated and fair comparisons could not readily be made. The first time arsenic was consistently used and in such a manner that comparisons of its effect could readily and fairly be made was in its use in conjunction with selenium for decolorization. It is, moreover, a general belief among glass makers that the small amount of arsenic added to the batch is completely volatilized from the glass early in the melting process; if such were the case, it would be difficult to see how the arsenic could affect the block near the working end of the tank. That the arsenic is not completely volatilized from the glass is evidenced by the effect which it exerts on the selenium color not only during melting but during the entire period the glass remains subjected to heat. Moreover, numerous published examples of glass analyses show the presence of varying amounts of arsenic in the glass. To endeavor to find about what is the ratio of the amount of arsenic remaining in the glass to the amount added to the batch, I examined two samples of soda lime glass, one taken from in front of the dog-house about eighteen inches below the surface, and the other taken from in front of the throat. The batch from which the glass was made contained about three pounds of arsenic per ton of sand. Analysis of the dog-house sample showed that 65–70% of this amount remained in the glass and the throat sample showed that 45–50% remained. Considering the length of time the second glass must have been under the action of heat, it would indicate that the arsenic compounds present must be quite stable to glass mixtures at melting temperatures. It is probable that the arsenic is present in the form of sodium arsenite.

It is not very clear why the presence of these arsenic compounds should exert a corrosive action on tank blocks, but it would appear from the above evidence that such an action does take place. As the glass sinks toward the throat and slowly cools, part of the arsenic compounds which in the upper hot layers remained dissolved in the glass, slowly separates out of solution, and it is this separated material which exerts the corrosive action on the throat. Relatively small amounts of salt cake can cause a considerable increase in the attack of the glass on the block and it is possible that the action of the arsenic compounds is similar but is more intensive due to the evident greater stability of the arsenic compounds to the action of glass at melting temperatures and to a slower rate of volatilization. The amount of arsenic remaining in the glass will not be constant, but will depend greatly on the oxidizing or reducing conditions which obtain in the batch and tank.

1689 W. Third Ave.
Columbus, Ohio

A SLIP PAINTING PROCESS SUITED TO THE CRAFTSMAN WHOSE EQUIPMENT IS LIMITED[1]

By D. W. Cox

ABSTRACT

The raw materials of the common stoneware business are used. The temperature needed is that of the maturing point of Albany slip, or cones 6 to 9. The kiln should be one designed to stand up under rather high temperatures. The ware is essentially once fired common stoneware decorated with a slip painting process.

Introduction

Common stoneware clays are those most often offered to the teacher and craftsworker by the potteries willing to supply prepared clay. Such clays seldom mature to the proper density when used with the matt and clear glazes generally used in schools and studio potteries so that leaking vases result. The process here described has the merit of overcoming this trouble, there is no crazing, and being fired only once, labor is saved for the craftsworker.

Equipment

The kiln should be one guaranteed by the manufacturer to stand up well under the temperatures necessary to mature glazes demanding cone 9, and better yet, one designed to use for hard porcelain work up to cone 18 if need be.

The ware are best formed on the potter's wheel.

A cheap air brush outfit such as sign writers use, or even the mouth spray used in charcoal drawing work, a few good camel's hair brushes, and a few orange wood modeling tools comprise the equipment, together with the wheel and kiln. The ware may, however, be built or modeled providing they are kept well softened at all stages of the work.

Technique

The process can best be described by giving the steps in a concrete example. The illustration herewith shown is of a vase made free hand on the potter's wheel, not turned down, but used as it came from the wheel. The handle is drawn, like a common jug handle. Since the whole work is that of men untrained in the fine arts the example is frankly the offering of the humble.

As is true with all slip painting done on the leather hard piece the artist must understand that work must either be done very rapidly or else work must be done in a rather moist room, with no drafts of air and with fre-

[1] Received December 29, 1924. Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, Feb., 1925. (Art Division.)

quent additions of moisture to the piece, which additions can best be done with the air brush. The softer the piece is while being painted the better the slip will adhere.

The example was decorated by first laying a ground of brown which is not very thick so that the buff gray of the stoneware body shows through it. The bulk of the slip added is white, but part of the decoration is made from the slip mixed with a good underglaze blue stain, while brown is mixed with part of the slip for other parts of the design.

FIG. 1.

The effect sought is that of early spring. Since the glaze used carries zinc oxide it is not possible to get either a pink or green. The craftsman, being untrained in ceramic chemistry, was forced to work with a very limited color palette, so that blue, brown and white and the natural color of the fired clay limited the colors possible.

After the ground is laid the slip is painted on and where desired is modeled.

When the piece is bone dry it is simply dipped all over in the glaze and the bottom is scraped clean of glaze, or in the terms of the potter the bottom is "fettled." The piece is then set into the kiln on its own bottom and fired to the proper temperature.

In the case of the example shown the firing was done in a commercial kiln, in about 48 hours. In the small portable kiln the firing should vary with the size of the piece but 18 hours should be about right. About 12 hours should be devoted to reaching cone 1 and the balance of the time from cone 1 on up to the maturing point, which will be not less than cone 6 and not more than cone 9.

Raw Materials Needed

Any prepared stoneware clay will probably work quite well. In the example shown the clay came from Brazil, Indiana, and is the clay from just below the block coal seam. The colors are the ordinary underglaze colors that can be had from any of the advertisers of such supplies whose names appear in the *Journal*. The raw materials for the slip can be had also from advertisers in the *Journal*.

THE SLIP

Feldspar	8
China clay	16
Ball clay	18
Flint	9

Use when of the consistency of tube paints.

THE GLAZE

Feldspar	53
Zinc oxide	10.5
Whiting	10.5
Flint	9
China clay	2
Ball clay	7

Use when weighing mixed with water 19.5 ounces to the pint.

Both slip and glaze can be prepared by soaking the weighed materials in plenty of water in stoneware jars over night, then mixing well with the hands and then passing the suspended mixtures through 60-mesh sieves. Allow the mixtures to settle and decant the surplus water, or else syphon off with a rubber tube. The slip will have to stand for some days before all the water can be removed and after that it should be allowed to stiffen slowly by evaporation until of the right consistency. When the slip is right it should be stored in sealed jars to keep it from drying out too much. The glaze will of course be rather thin, when the dipping is done.

If the experimenter will make use of glazes free from zinc oxide the color palette may be expanded. The process should work well in conventional decoration.

AMES, IOWA

SELECTION OF FIRE BRICK BY COMPARATIVE TESTS WITH A DETAILED DESCRIPTION OF THE METHOD USED TO MEASURE THE TEMPORARY EXPANSION OR CONTRACTION OF FIRE BRICK AT VARIOUS TEMPERATURES[1]

By F. A. Kohlmeyer[2]

ABSTRACT

This paper discusses the laboratory tests employed by the Electric Light and Power Company with which the author is connected, in selecting several brands of fire brick suitable for use in the construction of a power plant. A detailed description is given of the method used to measure the temporary expansion or contraction of fire brick at various temperatures and the procedure followed in the inspection of fire brick briefly outlined.

The testing and inspecting of fire brick by the purchaser has not until recently been given serious consideration. In fact it has been the demand of industries for refractories of a higher class and the difficulty of obtaining these which probably influenced many purchasers to determine for themselves the reliable sources of materials for their requirements.

It was the demand for a fire brick capable of withstanding a heavy load while under temperature as well as a brick which had a minimum tendency to spall, change its physical dimensions or collect slag while in service, which prompted the Electric Light and Power Company with which the author is connected to run laboratory tests upon about thirty brands of brick.

Description of Power Plant

A brief description of the powdered fuel furnaces in a new power plant which will have an ultimate capacity of 300,000 kw., should give an appreciation of the importance of selecting refractory materials of a high class for its construction.

The boilers are of the Stirling W. type and are designed for a steam pressure of 415 lbs. per sq. in. with a steam temperature of 700°F. The steam drums are 48 inches in outside diameter, with plates 2 inches thick. The heating surface of the boiler proper excluding the hearth screen boilers is 29,087 sq. ft.

The furnace is built with double walls, with air circulation through the intervening space tending to keep the wall cool and to warm the secondary air for combustion.

The height of the combustion space from the bottom of the furnace to the bottom of the center steam drum is about 60 feet. In plan the furnace is 23 x 34 feet and the furnace volume is about 25,140 cubic feet.

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[1] Recd. Dec., 1924. Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, Feb., 1925. (Refractories Division.)

[2] Office of the Inspection Division, Purchasing Department, The Detroit Edison Co.

The Test Made on Refractories

The Company realized that a laboratory test could do no more than indicate several brands of fire brick most worthy of a thorough trial in actual service. Consequently at the completion of the tests, four brands of brick were selected which seemed best adapted to give the service required in the operation of the powdered fuel furnaces of this plant.

From the results of service tests to date we can say that the rating given the various brick in the laboratory has been quite accurate.

The tests conducted by the Research Department, of this Company, and particularly the method used in measuring the expansion of fire brick while under temperature, or temporary thermal expansion, will here be described.

1. Spalling The spalling tests were first conducted on all brands under consideration in order to eliminate the most undesirable brands from the more extensive tests which were to follow. In order to get comparative data on brick known to give different results in service, a few of the brands giving poor results in the spalling test were carried through the entire test schedule.

The spalling tests were conducted in a standard carborundum lined oil-fired furnace and in accordance with instructions of the American Society of Testing Materials (Serial Designation C38-21T). The alternate heating and cooling of each brick was repeated only 10 times, however, or until it broke across the face and the brick given a rating depending upon the loss in weight and the number of water dips it withstood. The loss in weight of a brick which broke during the test was considered as 100%. Four samples of each brand were used and the average result of the four taken as the value of the test.

2. Physical Dimensions Tests Ten brick of each brand were put face to face and were measured for total thickness, width and length.

3. Cold Crushing Strength This was obtained by testing three bricks of each brand in a standard type compression machine. The brick were placed in the machine in an upright position and the ends protected by asbestos pads to obtain an even bearing surface.

4. Hot Load Tests These were conducted, with the exceptions noted, as outlined by the American Society for Testing Materials (Serial Designation C16-20) using a furnace slightly larger than the standard test furnace specified, but similar in general design. Tests were run with loads of both 25 and 40 lbs. per sq. in. on the brick.

The brick was heated to 2462°F (1350°C) at the rate specified and this temperature maintained for 2 hours instead of $1^1/_2$ hours as is usually done. Care was taken to maintain an oxidizing atmosphere in the furnace as it

was found that a reducing atmosphere appreciably affected the fusion temperature of certain brick under test.

The load of 40 lbs. per sq. in. was used, as brick in service in the large powdered fuel furnaces of the new power plant are actually under this load. The average result of three samples from each brand was taken as the result of this test.

5. Permanent Linear Expansion or Contraction Tests

These were run in the usual manner as outlined by the American Society for Testing Materials (Serial Designation C27-20) and it is therefore unnecessary to describe them. Three brick of each brand were used in this test.

6. Temporary Thermal Expansion Tests

A rather unique method was used to obtain the expansion of fire brick at various temperatures. It was considered important to obtain this information regarding the various fire brick under test as the temporary expansion indicates the probability of internal strains being set up in the brick on reheating, as well as the overall expansion of a wall made of these brick. The temporary expansion of fire brick is doubly important when these are to be used in the construction of furnaces as large as those in this plant where the furnace walls are over 60 feet in height.

A standard type of oil-fired testing furnace was used in determining the temporary expansion. This furnace was carborundum lined and equipped with a carborundum hearth to prevent an impingement of the flame on the brick under test.

The brick samples used for this test were those which had been previously used for determining the permanent expansion or contraction.

Two holes about $1/2$ inch deep and 7 inches apart were drilled in the front top edges of each brick. Orton cones, having a fusing temperature well above that at which the furnace was to be run, were cemented upside down, into these holes with carborundum cement. The cones were placed so they projected about $1/4$ inch above the face of the brick and the brick then placed in the test furnace previously described. The door of the furnace was bricked up and two 1-inch carborundum tubes placed horizontally so the Orton cones projecting above the top edge of the test brick were plainly visible to a person standing in front of the furnace and sighting through the tubes. The carborundum tubes, which extended from the face of the test brick and completely through the bricked-up door of the furnace, were employed to prevent a possible distortion of the line of vision due to the rapid movement of the hot gases.

A surveyor's transit was mounted on a substantial pier in front of the furnace in such a position that the Orton cones were visible through the carborundum tubes when sighting through the transit.

The transit was carefully leveled and the intersection of the vertical and horizontal cross hairs brought to focus on the inside top edge of one of the Orton cones. The telescope of the transit was then plunged or inverted through a vertical plane and focused on a steel scale mounted at such a distance from the transit as would give a suitable multiplication of the distance between the Orton cones. A diagram of the set-up is shown in Fig. 1.

By sighting on the Orton cone on the other end of the brick, plunging the telescope and obtaining another reading on the scale, two isosceles triangles were formed with the transit at the apex of each. The distance between the cones was the base of the smaller triangle, while that same distance enlarged and projected on the steel scale was the base of the larger triangle. Care was taken to see that the bases of these two triangles were parallel and that the steel scale was level.

In order to improve the accuracy with which readings could be taken, two movable trammels were mounted in such a position that their points

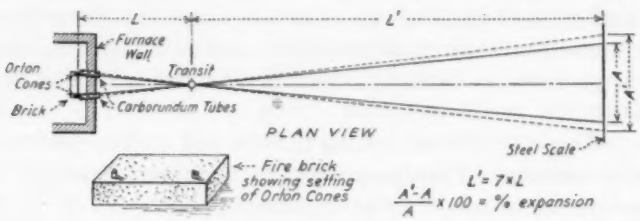

FIG. 1.

just projected over the lower edge of the scale. The trammel points could then be set to coincide with the intersection of the cross hairs of the transit and the multiplied distance between the cones accurately determined on the scale. A magnifying glass was used to insure accurate scale readings.

After obtaining a reading on the scale with the brick at room temperature, the brick was heated and the distance between the Orton cones, as multiplied on the scale, determined for both 2000°F and 2500°F.

Since the distance measured on the scale was directly proportional to the distance between the Orton cones mounted on the brick, the percentage of expansion could be calculated from the scale readings. The percentage of expansion was determined for both 2000°F and 2500°F and the average result of three samples of each brand recorded as the result of the test.

7. Brick-Cone Softening Temperature Tests

These tests were conducted as outlined by the American Society for Testing Materials (Serial Designation C24-20) using a standard type of gas fired testing furnace.

8. Coal-Ash Penetration Tests

These were run by filling 2 drilled holes in each brick to be tested with coal ash. The brick were then placed in a brick testing furnace and heated to 2500°F at the rate prescribed by the American Society for Testing Materials and maintained at this temperature for two hours. The brick were allowed to cool in the furnace and were then cut in two through the holes and an attempt made to determine the ash penetration. The results of this test were unsatisfactory as it proved to be difficult to determine the depth of ash penetration.

9. Coal-Ash Brick Cone Softening Temperature Tests

As the coal-ash penetration test was not conclusive, this additional test was made to determine the ability of the brick to resist the slagging action of coal ash.

It is clearly evident that the extent to which the fusion temperature of brick is affected when in intimate contact with coal ashes, measures their ability to resist slagging when in service in the boiler. This reaction, however, is chemical rather than physical and consequently some account must be taken of the coarseness of grind and porosity of the brick when considering the tendency to slag.

Cones were made of composite samples of the pulverized brick material to which were added coal ashes in varying percentages. The softening temperature of each mixture was determined on duplicate samples in the same manner as in the brick-cone softening temperature tests.

The results seemed to indicate that the slagging action of coal ash is due to the iron content of the coal. This conclusion was reached after using coals having both high and low percentages of iron.

While this test is chemical rather than physical, the results nevertheless were of considerable importance.

Inspection

The Inspection Division of the Purchasing Department of this Power Company is responsible for the inspection of all material bought on specification or otherwise subject to inspection.

In the case of fire brick, each shipment is given a visual inspection and if deemed necessary, checked for conformity to specifications by conducting tests similar to those outlined above.

If a shipment is not in accordance with specifications it is either rejected by the Inspection Division, or accepted provisionally dependent upon an adjustment between purchaser and vendor. This frequently takes the form of a price adjustment in conformity with the actual material received. At other times defective material received is replaced by the vendor.

It has been the experience of this Company that inspection actually pays

on a plain debit and credit basis although the indirect savings are far more important.

The inspection and testing of fire brick has been beneficial in that it has resulted in locating several reliable sources of material. It has led to more efficient construction as well as more economical maintenance of boiler furnaces.

Inspection has also had an effect on the manufacturer of fire brick which is of great significance in that it has helped to force a development of the art.

An example will assist in illustrating this point. Several carloads of fire brick received by this Power Company from a certain vendor were flatly rejected as they were not within the specified and generally accepted tolerances for size. This action naturally led to some controversy, resulting, however, in the fire brick manufacturer voluntarily scrapping all of his old molds, dies, press boxes, etc., at a considerable expense.

Later the vendor frankly expressed his satisfaction at the results of this step, which judging from present developments toward the establishment of standard sizes in fire brick, would have been inevitable at some later date.

DETROIT, MICH.

Discussion

M. C. BOOZE:[1] At a time when fire brick specifications are becoming the vogue and greater attention is being paid to the quality of the refractories used than ever before, it is interesting to know that the standard tests can be used to distinguish between brick which give satisfactory and unsatisfactory performance in service.

It is unfortunate that comparative results are not given, especially on the coefficients of expansion, as there are few published determinations which were made at temperatures as high as those described in this paper.

To the writer, it appears that the use of the spalling test to eliminate some of the brands of brick from further tests is questionable. The use of powdered coal furnaces, such as described, is comparatively new in power plants and the performance of refractories in them has not been thoroughly studied. It seems, however, that rigidity under load and lack of shrinkage on the 9-inch brick would be of greater importance than spalling. The holding tile in the hollow wall construction should undoubtedly be tested first for spalling resistance, as they are comparatively large shapes.

Neither is it considered advisable to stop the spalling test at the end of ten dips. This would suffice to distinguish between brands which were good and bad in spalling properties, but would not show sufficient difference between some brands of first quality brick and the specially developed products which give exceptional spalling results.

[1] Mellon Institute, Pittsburgh, Pa.

AN ELECTRIC FURNACE FOR SOFTENING POINT DETERMINATIONS[1]

By W. L. Pendergast

ABSTRACT

This paper presents a description of an electric resistance type furnace which has been designed at the Bureau of Standards for the determination of softening points of ceramic materials. The advantages claimed for this furnace are simplicity of design, with resultant low cost of manufacture and repair, economy in operation, high temperatures available, sufficient accuracy in determining softening points in terms of standard cones or actual temperature readings, and compactness of installation.

Introduction

A furnace to be used for the purpose of obtaining softening points, and which can be constructed in any plant having the facilities to fire clay products, is a desirable asset for plant control and would justify its installation by practically every concern manufacturing refractories because of its low initial cost and maintenance. Gas-fired furnaces have been adopted for this purpose, but their use is limited due to the difficulties encountered (1)in obtaining extreme temperatures while maintaining oxidizing conditions, (2) in determining these temperatures by means of the optical pyrometer and (3) in observing the cone plaque. High temperature gas furnaces also require compressed air, or gas, which, if not available, often necessitates the installation of expensive apparatus. Furnaces depending on electrical energy for heat seem to be the most easily adapted to designs for general and economical use.[2] Inductance types, and those using metallic resistors, are ideal, but the cost is generally prohibitive where temperatures required to fuse clays are to be obtained. For several years the Bureau has experimented with various carbon resistance furnaces, having in mind the development of a design which could be generally adopted by the ceramic industry.

Description of Furnace

A softening point furnace of simple construction, the parts of which are easily replaced, and which has given satisfactory service for the past two years in the ceramic laboratories of the Bureau, is shown in Fig. 1. This furnace consists essentially of a fire clay shell surrounding a carbon re-

[1] Recd. Jan. 2, 1925. Published by permission of the Director, Bureau of Standards, U. S. Department of Commerce. Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, February, 1925. (Refractories Division.)

[2] Samuel A. Tucker, *Electrochem. and Met. Indus.*, **5**, 227 (1907); A. Coggeshall and A. V. Bleininger, *Trans. Amer. Ceram. Soc.*, **10** (1908); W. Pip-Darmstadt, *Zeits. für Elek.*, **16**, 664 (1910); D. F. Calhane, *Sci. Amer. Suppl.*, **71**, 207 (1911); A. V. Bleininger and G. H. Brown, Bureau of Standards, *Tech. Paper* **7**; Liddell's "Handbook of Chemical Engineering," p. 478.

sistance element in which the heat is generated and which in turn surrounds a magnesite muffle. The trial cone plaques are placed in this muffle for test and in this manner are protected from reducing gases generated in the resistor. The entire furnace is enclosed in a sheet iron casing and mounted on an adequate stand.

The fire clay shell need not be of especially refractory material, but should resist spalling. This shell is simply a cylinder with three lugs to support the carborundum ring (*C*) shown in Fig. 2 and was pressed in a sheet iron mold. The shell rests on a fire clay disc (*A*) of the same material which is provided with a seating for the shell and the magnesite muffle. The carborundum ring (*C*) which is used to restrict the graphite electrode at the high temperature zone is made of a mixture of 95% No. 80 carborundum and 5% plastic kaolin, to which enough water is added to permit pressing into shape in a suitable mold. The magnesite muffle, seated in the fire clay base (*A*) and extending above the body of the furnace, is composed of four cylinders approximately equal in length and so placed that there is no joint in the zone of highest temperature. The individual cylinders are composed of the purest commercial electrically fused magnesite which is ground to pass a 20-mesh sieve and is thoroughly mixed with an organic binder (preferably gum tragacanth) and hand-rammed in steel molds. When dry, these cylinders can be easily handled and before being used should be fired as high as facilities will permit. It has been found advisable to make these rings as dense as possible and to fire them at least to cone 16 to prevent undue shrinkage and attack by carbon when in service. The current is introduced by means of copper electrodes (*G*), Fig. 2. These electrodes are copper bands 3 inches wide and $^1/_4$-inch thick, which are bent into a ring conforming with the inside diameter of the shell and provided with a lug, protruding through a slot, permitting the attachment of wire leads. These bands offer a considerable surface because of their shape and will be cooled automatically if the lugs are permitted to protrude at least 6 inches from the outside of the furnace.

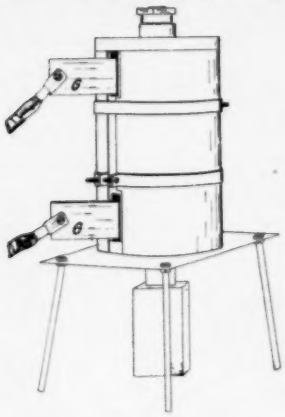

FIG. 1.

Having assembled the shell, base (*A*), the lower electrode, and the magnesite muffle, the space below the carborundum ring (*C*) is packed firmly with graphite or granular carbon. The ring (*C*) and the upper electrode are then put in place and the remaining annular space packed firmly with the material forming the resistor.

Care must be taken in packing the graphite evenly to obtain balanced

resistance.[1] In this connection it should be noted that in this design the possibility of a hot zone forming has not been definitely overcome, but if care is observed in packing the graphite the operator can, after a little practice, obtain a resistor which will in practically every case function properly.

It should be noted that by using this design of electrode the graphite or granular carbon can settle while the furnace is being operated and still maintain satisfactory contact. The advantages of flake graphite over carbon grains have been demonstrated since, with the former, arcs in the body of the resistor were not as liable to be formed. After packing the resistor the refractory cover (*B*) is put in place. This cover should be ground to fit as accurately as possible to exclude air from the graphite. The fire clay shape (*E*) assists in concentrating the heat at the center of the muffle and serves as a peephole through which the cone plaque may be viewed. This shape (*E*) was made by grinding a fire clay tile to the proper dimensions. The upper opening of (*E*) is closed by laying a piece of No. 6 welding glass on a thin sheet of kieselguhr.

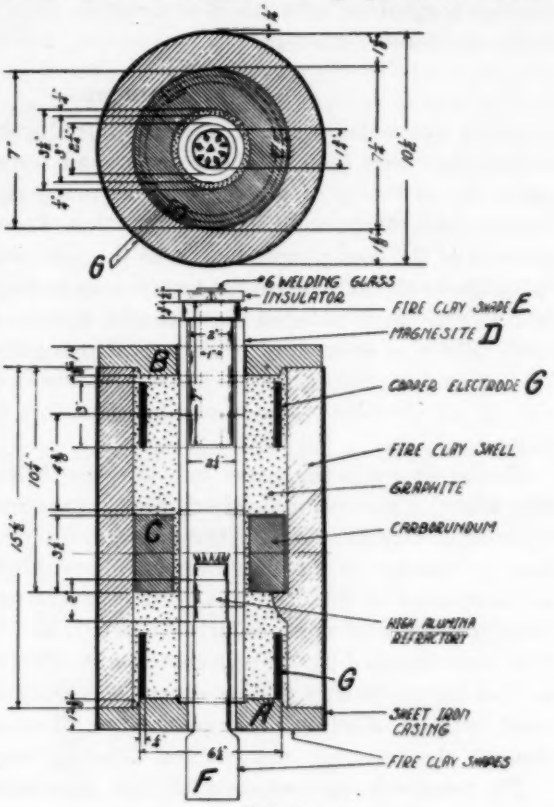

FIG. 2.

The cones are introduced from the bottom of the furnace and the plaque, usually made of a mixture of 50% calcined alumina and 50% plastic kaolin, rests on a base of the same material which in turn is supported by the refractory shape (*F*). This shape is made by so grinding a No. 1 refractory soap brick that when the shoulder is against the opening in (*A*) the cones

[1] O. P. Watts, "Granular Resistance Furnace," *Jour. Op. Soc. Amer. and Rev. Sci. Instruments*, 9 [6], 705 (1924).

are raised to the hottest part of the muffle, which is midway between the top and the bottom of the ring (*C*). This shape should not fit accurately in the opening, but permit a current of air to be drawn into the muffle during the operation. This current passes up through the hot zone and out at the upper end of the peephole (*E*), in this way replenishing the supply of oxygen in the muffle. The sheet iron casing which encloses the entire furnace provides the necessary added strength to the shell. The furnace is mounted on a stand as shown in Fig. 1 and can be placed on a table or wherever convenient.

Operation

In the operation of the furnace the introduction of the cones from the bottom has been found to be a decided advantage. This method eliminates the necessity of placing and removing cone plaques by means of tongs (which often results in the destruction of the test set) and permits the removal of the cone plaque as soon as the test cone has softened, which is a desirable asset. The saving of time is also an important factor since a new test set can be introduced conveniently without cooling the muffle below 1000–1200°C. If readings with optical pyrometers are desired, they can be obtained by mounting the instrument above the furnace and sighting directly on the cone plaque through a relatively small opening in the insulation.

Results shown in this paper indicate that the errors in temperature readings due to reflection and radiation are comparatively small and the readings sufficiently accurate for the purposes intended. In this work an optical pyrometer of the disappearing filament type was used. In using an instrument of this type the opening in the furnace through which the telescope is sighted must be large enough so as not to cut in on the cone of light rays required by the pyrometer, *i. e.*, the hole must be large enough so that the pyrometer telescope may be moved a little from direct alignment without affecting the apparent brightness of the furnace as viewed through the telescope and without affecting temperature measurements.

The furnace is operated on a 220 volt alternating current line through a 6 kw., 60 cycle, 220 volt primary, 47 volt secondary transformer. A ratio board is tapped in between the transformer and the furnace and cuts down the secondary voltage in steps of 20, 10, 8, 6, 2 and 1 volts. An ammeter with a capacity of 200 amperes is used in this circuit to assist in regulating the temperature and to prevent exceeding the capacity of the transformer.[1] This furnace, when connected with a 220-volt circuit having an 80% power factor and operated for seven hours, will consume 16.8 kw.-h., or an average of 1.68 kw.-h. for each of ten softening point determinations.

[1] It is recommended that a 10–12 kw. transformer be used. The transformer and ratio board may be purchased for approximately $250.

Several rates of heating have been tried and the most satisfactory results were obtained by increasing the temperature by about 400°C per hour for three hours, which insures uniform temperature throughout the hot zone. From this point it is very easy to increase the temperature according to the requirements specified for this test by the A. S. T. M. The maximum temperature reached in this furnace was 1830°C, but the magnesite rings deteriorate rapidly above 1750°C.

The length of service of the furnace will, like all other furnaces, depend upon the treatment it must undergo. The magnesite muffle will be the first part that must be replaced, but this operation, as will be noted from the drawing, is a simple one. The carborundum ring can be used successfully for about ten heats and its replacement is also easily accomplished. The other parts of the furnace are affected very little and their replacement cost is practically negligible.

Results

The data shown in the following tables are representative of results obtained in the determinations of softening points of various materials.

The temperatures shown in Table I are the results of several check

TABLE I

The temperatures obtained by using the furnace described are those readings of an optical pyrometer when sighting directly on orton pyrometric cone. The rate of heating was that specified in the A. S. T. M. standard method of test for softening points, serial designation C24–20, and the temperatures given are those noted when the tip of the cone touched the plaque

Cone number	Temperature in °C		
	Kanolt's Orton's	Hoffman's Seger's	Author's Orton's
26	1600	1580	1550
27	1630	1605	....
28	1635	1610	1590
29	1650	1625	1605
30	1670	1640	1630
31	1670	1640	1650
32	1705	1670	1670
33	1720	1680	1690

tests and are believed to be accurate within 25°C. They agree as well as can be expected with the values obtained by Kanolt[1] and are in accidental agreement with the results obtained by Hoffman[2] determined in the Reichsanstalt on German cones. We could reasonably account for even a greater difference between our values and those given by Hoffman con-

[1] Bur. Stand., *Tech. Paper* **7**, p. 15.

[2] *Tonind. Zeit.*, **33**, 1577 to 1580 (1909).

sidering the difference in temperature scale of the two national laboratories and the difference in the cones themselves.

The data shown in Table II compare the results obtained in the electric furnace described and a gas-fired furnace of the surface combustion type.

In Table III we have compared results obtained in our furnace with those obtained in an Arsem furnace (a graphite resistance, vacuum furnace).

TABLE II

Some results which were obtained in a gas-fired furnace of the surface combustion type formerly used at the bureau compared with those obtained in the electric furnace described. The results are shown in cones only since even fairly accurate temperature measurements are difficult to obtain in a gas-fired furnace

Material	Sample number	Softening point (cone number) as determined in gas-fired furnace			Softening point (cone number) as determined in electric furnace		
		(1)	(2)	(3)	(1)	(2)	(3)
Mo. Fire Brick	1	30	30	32	32+	32+	32+
Mo. Fire Brick	2	33	33+	..	33+	33+	..
Mo. Fire Brick	3	32–33	32–33	32–33	32–33	32–33	..
Pa. Fire Brick	1	34	34+	..	33—	33—	33—
Pa. Fire Brick	2	28	28	..	28+	28+	..
N. J. Fire Brick	1	30	31	31	30	30	30
N. J. Fire Brick	2	30	30–31	31	30	30	30
N. J. Fire Brick	3	32–33	32–33	..	32–33	32–33	..

TABLE III

Relation of softening points as determined respectively in an Arsem furnace and in furnace described

Test specimen, fire brick	Arsem furnace, degrees C	Author's furnace	
		Degrees C	Cone
A	1620	1605	28+
B	1625	1610	29
C	1645	1640	30+
D	1670	1660	31–32
E	1680	1680	32+

In the Arsem furnace the samples were protected from the reducing gases of the graphite heater by a sillimanite tube. Being heated in a vacuum there could be no oxidation. The rate of heating was 10°C per minute and the softening point was taken as the temperature at which the sample was distinctly seen to flow. This method is one which has been used in the Pyrometry Section of the Bureau, where temperature measurements are standardized and where our optical pyrometer was calibrated. One may use this comparison with due attention to the fact that small differences should be expected since different methods were used in obtaining softening point.

The softening points of various commercial grades of silica were all

found to be about 1690°C which is in fair agreement with results obtained by Kanolt[1] on the melting point of silica brick.

Remarks

The advantages of this type of electric furnace are: the high temperatures obtainable, oxidizing atmosphere in the muffle, ease of control and repair, economy in operation, sufficient accuracy in determining softening points in terms of standard cones or actual temperature readings, greater convenience due to the elimination of the noise of gas burners, the fact that the operator can make observations and replace test sets without danger of burns, and the compactness of the installations.

The author wishes to acknowledge his appreciation for the constructive suggestions and criticisms offered by R. F. Geller, during the development of this furnace.

[1] Bur. Stand., *Tech. Paper* 10, p. 16.

RUBBER GRINDING MILL LININGS AND RUBBER AS A MATERIAL TO RESIST ABRASION[1]

By B. W. Rogers

ABSTRACT

For the benefit of those who are skeptical about the ability of rubber to resist abrasion, attention is called to the fact that a rubber tire wears much less than skid chains on a brick pavement. Rubber linings in ball mills are found more efficient than steel linings in respect to capacity, fineness of grind, and power consumption. One test on cement using both a rubber and a steel lined mill showed a 20% greater capacity, 10% less power consumption and 0.9% more material through 200-mesh. Other advantages of rubber linings are: weight of mill decrease and volume increase, reduction of maintenance costs, minimum contamination of materials being ground, and possibility of jointless and detachable linings.

It has been the popular theory that it took a very hard surface to resist abrasion successfully. This accounts for the selection of imported silex and alloy steels for the lining of grinding mills. Every grinding mill operator knows the excessive cost and delay which are incident to the replacement of worn liners and it was with this thought in mind that the idea was conceived to make the grinding mill liners of rubber. No doubt the suggestion came from the remarkable service rendered by the rubber tread on the automobile tire and to those who are unfamiliar with that peculiar property of rubber to resist abrasion, the example of the tire tread and the skid chain will visualize a basis of comparison.

Everyone who has driven a motor car and has used skid chains knows that a few hours of driving on brick or concrete roads will wear the alloy steel links to a point of failure, while in the same period of time a tire tread will not show a sign of abrasive wear.

The idea of using rubber as a grinding mill lining originated in Canada and was first made use of in the mining industry. The early experiments proved highly successful and it has been conclusively demonstrated that rubber lining can, under average conditions, commercially compete with stone, iron or steel lining on a cost and service basis.

Capacity and Efficiency

When the rubber lining was introduced, one of the first questions asked was regarding the capacity and efficiency. Rubber being a soft material, it is quite natural to assume that a certain amount of grinding is eliminated by the grinding media contacting on the soft surface. It was observed that mills with rubber linings had a higher grinding efficiency than when the same mills were lined with steel. The term "grinding efficiency" in this instance takes into consideration the three important factors (1)

[1] Presented at the Annual Meeting, American Ceramic Society, Feb., 1925, Columbus, Ohio. (Enamel Division.)

capacity (weight of material ground per operating time); (2) fineness of finished product in relation to the feed, and (3) power consumption. Rubber lining increased the efficiency in excess of 10% as compared with the steel lining.

A large cement company saw the possibilities in the rubber lining for the fine grinding of cement slurry and offered their coöperation in making operating tests. Steel and rubber lined mills were operated in parallel and observations were made varying all operating conditions such as dilution of feed, speed and grinding charge. Also, lights were extended into the mill so that the action of the grinding charge could be observed and studied. After some manipulation conditions were determined where the mills under test would operate most efficiently and the figures quoted below represent the best result with No. 1 mill operating with a rubber lining in comparison with the best results obtained from No. 2 mill operating with steel lining.

	Rubber	Steel
Gallons of slurry per hr.	2090	1740
Tons reduced to dry material.	9.76	8.15
KWH per ton.	13.5	14.88
Fineness.	94.1–200-mesh	93.2–200-mesh

An analysis of the figures just quoted will show a 20% greater capacity for the rubber-lined mill with about 10% decreased power consumption and at the same time an increase in fineness of finished product by 0.9% through 200-mesh.

All of the experimental work to date has been accomplished in mills of the continuous feed and discharge type. There is no evident reason why the lining will not give about the same performance in the batch type pebble mill commonly used in the ceramic industry.

It was found that slippage between the shell liner and grinding media is detrimental to a violent action of the balls or pebbles. When slippage is eliminated or reduced to a minimum, the grinding media travels in a well-defined path giving a maximum of moving contact within the grinding media itself.

In replacing a stone liner with rubber the volume of the mill will be increased. Also a substantial weight will be taken off of the trunnions to allow for the possible increase in weight of the effective charge.

Probably the outstanding justification for the rubber lining is its exceptional wearing ability which will allow continuous operation over a long period of time and substantially reduce maintenance cost.

In enamel grinding rubber will conform to another important requirement, namely, the elimination of contamination. After the first few hours of operation contamination from the rubber is negligible and the smooth,

impervious surface of the rubber lining can be quickly washed clean when change of grade or color is required.

A Jointless Lining

The Goodrich Company has perfected an integral bonding of soft abrasion resisting rubber. This will eliminate joints and make a leak-proof lining. This process involves a special preparation of the metal parts, therefore, it will be necessary to send such parts to the factory for the placement of the liner. This is recommended for all mills under three feet diameter. The mill will have a detachable head as it is impossible to work through small manholes.

A Detachable Lining

The rubber can be furnished in sheet form with or without fabric back and can be secured by rubber covered retaining bars. There is also the possibility of making a false lining of sheet metal to which the rubber can be applied at the factory.

For straight cylindrical type mills larger than three feet diameter, a removable wave type liner has been designed which incorporates a totally covered steel retaining bar by means of which a positive anchorage is made with bolts. The slabs are of such size that they can conveniently be entered through a standard manhole.

The experiments to date with the wave type lining show that it practically eliminates slippage of the grinding media and creates an ideal action within the mill.

The compounding laboratories have produced a new compound which will be known commercially as "Linerite." This rubber compound is without question the best abrasion resisting test on the market today and offers possibilities of application wherever a protective coating to resist corrosion and abrasion is required. It is being used successfully in mining plants, cement plants and stone washers and is particularly desirable when mounted on sheet or plate metal, giving the qualities of a rubber surface combined with the strength of steel. This new product can be worked much the same as sheet metal, its only limitation being that it cannot endure heat in excess of 150°F.

B. F. Goodrich Rubber Co.
Akron, Ohio

CERAMIC ABSTRACTS

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[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from *Chemical Abstracts* by coöperative agreement.

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Abrasives

Natural abrasives (Can.). V. L. Eardley-Wilmot. Can. Inst. of Min. and Met., *Bull.* **155**(1925).—Grindstones, scythestones and pulpstones; production, producing localities with statistical table, 1909–1923; prospecting producing areas; mining and methods of prepn. for market; uses and disposition; and prices and present market conditions are discussed. The econ. factors of garnet, corundum, volcanic ash, pumice, and diatomaceous earth in Canada are further surveyed by W. O. P. R. O.

Abrasives. Anon. *Imp. Min. Resources Bur.* (1925).—Abrasives (1920–1922). O. P. R. O.

PATENTS

Antislip floor. Frank J. Tone. U. S. 1,528,638, Mar. 3, 1925. An antislip floor or tread having embedded in fragments of a self-bonded mass of abrasive grains united without a separate binder under high temp.

Aluminous abrasive material and method of making the same. Frank J. Tone. U. S. 1,528,639, Mar. 3, 1925. A mass of aluminous abrasive grains united to each other by fluxed portions of their matrix mat. the grains retaining their individual charac.

Dressing of smelted, artificial abrasives. Hugo Vierheller. Ger. Pat. 399,725. *Chem. Zentralblatt*, **2** [14], 1844(1924). Sulphite liquor is distributed in the hydrous dispersion medium and, after fractionating, the sepn. in flakes of the elutriated mat., which is still suspended, is obtained by adding permanganate or alkali. The method allows to sep. abrasives in various sizes. W. S.

Art

Note on the use of fluorspar in leadless glazes. J. W. Mellor. *Trans. Ceram. Soc.* (Eng.), **23,** 178(1924).—Small scale expts. made by M.'s students indicate that the standard leadless glaze can be softened by the replacing part of the lime, up to about 6%, by fluorspar and cryolite. Care must be taken in using fluorides in glazes since under conditions not definitely detd. at present they may produce blisters. H. F. S.

Some old directions for making the purple of Cassius and vitreous enamel pigments. Wilhelm Frommel. *Chem.-Ztg.*, **48,** 777(1924).—Directions for making various prepns. used in the art glass industries, contained in a manuscript dated 1835, are quoted literally. Urine is prescribed as the reducing agent for making Cassius purple. Yellow glaze consisted of red lead and sand; green glaze, of MnO_2, Pb_3O_4 and sand.

F. A. W. (*C. A.*)

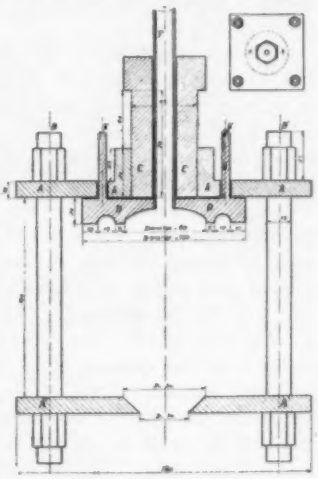
PATENTS

Titanium hydroxide and pigments. J. BLUMENFELD and C. WEIZMANN. Brit. Pat. *Oil and Colour Trades Jour.*, **67**, 618(1925).—The hydrolysis of solns. of titanium sulphate for the production of titanium hydroxide is effected by adding a titanium soln. to another of different concn. or to water and allowing diffusion to take place for several min. before complete mixing is effected. In an example a paste of titanium sulphate crystals is introduced into twice its vol. of boiling water and is maintained at boiling temp., the mixing being effected after 3 to 5 minutes. The hydrolysis is effected in about half an hour. In another example a strong soln. of titanium sulphate is introduced little by little into half its vol. of boiling water and afterwards stirred, the temp. being maintained near the b. p. The hydrolysis is effected in about 1 hr. The process may be effected in presence of other subs. which it is required to incorporate with the titanium hydroxide for the production of pigments, and such subs. may be prepd. sep. or in the app. in which the hydrolysis is effected. The subs. mentioned are barium sulphate, calcium sulphate and silica. O. P. R. O.

Manufacturing of metallic coats by firing in solutions of speculum metal. EMIL REINHOLD EICHLER (Dresden). Ger. Pat. 401,737, *Chem. Zentralblatt*, **2** [22], 2550 (1924). The soln. employed contains a mixt. of organic Cu-, H_3BO_3-, Bi and Pb-compds. and is fired in at temp. of 330–470°C; copper colored coats are obtained. To produce gold or silver similar coats the soln. contains besides the compds. mentioned organic Ag-Ni and Sn compounds. As organic ingredients serve resin, sulphurous resins, etc. W. S.

Cement, Lime and Plaster

Testing the permeability to water of mortars, brick, stone. F. ANSTETT. *Rev. Mat. Constr. Trav. Pub.*, **183**, 309–13(1924).—Permeability of a subs. is the property characterized by the actual passage of fluids through it, whereas porosity merely indicates the presence of voids and pores which may be filled up with fluids. A. indicates the older methods of detg. permeability as prescribed by the (French) Commission of Testing Methods in 1891, 1894 and 1900, in which a glass tube was cemented into place in a block of the mat. to be tested. Water in the tube was kept at a const. head, and the permeability was expressed by the number of ls. of water flowing per hr. through a cubic block of definite dimensions. Later the TISSIER app. was developed for detg. permeability of many building mats. under varying conditions of water press. Two parallel plates *A* and *A'* are held rigidly in place by 4 bolts *B*. A copper tube *F*, soldered to the circ. metal piece *D* leads the water to the specimen clamped between *D* and *A'*. Thick rubber gaskets prevent the specimen from coming directly in contact with the metal. The specimen is usually 10 to 11 cm. square and 8 cm. thick. Water under definite press. is applied to the specimen through *F*, and the quantity which passes through the specimen is collected by a funnel in a graduated vessel situated below the app. L. N.



Experiments on the setting of Portland cement. JULES CARTIAUX. *Rev. Mat. Constr. Trav. Pub.*, **184**, 1–3(1925).—(1) *Free lime content.* Port. cement was mixed

with 10% sugar soln. The soln. of the free lime, in preventing the re-solution of the calcium aluminate, retarded the set almost completely. The free lime amounted to 4.2% CaO. The stability of vol. was poor. (2) *Sol. salts.* Fifty gms. of Port. cement were suspended in water to dissolve the sol. salts, and then filtered. The insol. matter after being dried at 100°C did not set, and on standing whitened due to carbonization. After 3 days the $CaCO_3$ content was 26%, after 3 months 31%. The sol. salts when mixed with the insol. matter did not induce the process of setting. (3) *Influence of air.* The initial and final periods of set were slightly prolonged when the Port. cement was allowed to set under mercury, that is, not in contact with the air. (4) *Influence of CO_2.* Similar results were obtained when Port. cement was allowed to set in an atmosphere free of CO_2. The stability of vol. in both cases was perfect. The outer coating of a test specimen after 1 month's exposure to the air contg. CO_2 corresponding to 32% $CaCO_3$, after 8 months 42.5%, after 5 years 80%. The interior of the piece after 5 years' exposure yielded but 5.5%. (5) *Weight loss study.* One hundred g. of Port. cement mixed with 26 g. of distilled water were held on a watch glass on a balance pan, to det. the rate of evapn. of water, and the absorption of CO_2. Four mins. after the time of mixing, loss of wt. was .05 g., from 4 to 20 mins. .01 g. per min., from 20 to 60 mins. .01 g. every 2 mins., from 60 to 150 mins. .01 g. every 3 mins., from 150 to 235 mins. .01 g. every 4 mins., from 235 to 240 mins. the loss dropped to .01 g. per min. as at the beginning, and here corresponded to time of initial set. From 4 hrs. to 4 hrs. 23 mins. loss was .01 g. per min., 4 hrs. 23 mins. to 4 hrs. 29 mins. .01 g. every 3 mins., 4 hrs. 29 mins. to 7 hrs. .01 g. every 4 mins., 7 hrs. to 7 hrs. 19 mins. .01 g. every 2 mins. At this point the Vicat needle did not penetrate, corresponding to the completion of set. 7 hrs. 19 mins. to 7 hrs. 24 mins. loss .01 g. every 4 mins. After 3 months the original wt. of 126 g. decreased to 118.05 g. (loss of about 6%). The initial set took place after a loss of 0.63 g. (0.5%), and the final set after a loss of 0.8–1.0 g. (0.7%). The increase in wt. due to the absorption of CO_2 was for the period 3–5 months .28 g., 5–11 months .20 g., 11–26 months .43 g., 16–24 months 1.13 g., giving a final wt. of 120.25 g. At this time the cement specimen contd. CO_2, the equiv. of 6% $CaCO_3$. L. N.

French specifications for slag cements. ANON. *Rev. Mat. Constr. Trav. Pub.*, **185,** 41–2(1925).—The foll. are the technical requirements of slag cements to be used in marine construction, issued by the Minister of Public Works in a circular dated Sept. 2, 1924. *Definition.* The slag cement shall consist of a mixt., properly proportioned and thoroughly mixed, of carefully slaked and bolted hydraulic lime and blast fur. basic slag, finely ground. *Chem. compn.* The cement shall not contain more than 5% MgO, 12% Al_2O_3, 2.5% Fe_2O_3, 2% sulphur. Ignition loss at white heat shall not be more than 5%. The index of hydraulicity, that is the ratio of wts. of silica and alumina as against the wts. of lime and magnesia shall be less than 0.70. *Fineness.* The cement shall at the most have a residue of 12% by wt. on a screen 4900 mesh per sq. cm., and 2% on 900-mesh. *Apparent d.* A liter of cement shall weigh at least 900 g. *Duration of set.* The cement immersed in potable water shall not begin to set before 1 hr. has elapsed. The final set shall not take place before 3 hrs. nor after 24 hrs. have elapsed. *Tensile strength of pure cement.* Briquettes immersed in sea water for 24 hrs. shall have a minimum tensile strength per sq. cm. of 18 kg. at the end of 7 days, 25 kg. in 28 d. In addition the tensile strength shall increase at least 3 kg. between 7 and 28 d. *Tensile strength of mortar.* Briquettes of the mortar immersed in sea water for 24 hrs. shall have a minimum tensile strength per sq. cm. of 8 kg. at the end of 7 days, 18 kg. in 28 days. Besides the strength shall increase at least 2 kg. between 7 and 28 days. *Hot and cold deformation tests.* Pats and briquettes shall be kept in a humid atmosphere for 24 hrs. and the pats shall then be immersed in sea water. The temp. of the hot deformation test for the briquettes shall be maintained at 100° for 3

hrs. The increase in length of the stand. spacing between two needle points shall not be more than 5 mm. L. N.

French specifications for aluminous cements. ANON. *Rev. Mat. Constr. Trav. Pub.*, **185,** 42(1925).—The foll. are the tech. requirements of aluminous cements to be used in marine construction, issued by the Minister of Public Works in a circular dated Sept. 2, 1924. *Definition.* Aluminous cement shall be produced by htg. a mixt. of alumina, silica, iron oxide and lime or calcium carbonate; and grinding the product. *Chem. compn.* The cement shall contain at least 30% Al_2O_3 by wt. It shall not contain more than 2% MgO nor more than 1% sulphur. The index of hydraulicity, that is the ratio between the wts. of silica and alumina as against the wts. of lime and magnesia shall be less than 1. *Fineness.* The cement shall at the most have a residue of 20% by wt. on a screen with 4900-mesh per sq. cm. *Apparent d.* A liter of cement shall weigh at least 900 g. *Duration of set.* The cement immersed in potable water shall not begin to set before $^3/_4$ hr. has elapsed and the set shall be complete in 7 hrs. *Tensile strength of mortar.* The briquettes immersed in sea water for 24 hrs. shall have a minimum tensile strength per sq. cm. of 27 kg. at the end of 2 days, 28 kg. in 7 d., and 29 kg. in 28 d. *Hot and cold deformation tests.* Pats and briquettes shall be kept in a humid atmosphere for 24 hrs., and the pats shall then be immersed in sea water. The temp. of the hot deformation test shall be 100°, and maintained for 3 hrs. The increase in length of the stand. spacing between two needle points shall not be more than 1 mm. L. N.

High early-strength Portland cements in Germany. G. HAEGERMANN. *Eng. News-Rec.*, **93,** 910–1(1924); *J. Soc. Chem. Ind.*, **44B,** 100–1(1925).—Ordinary Port. cement occupies a position intermediate between the hydraulic limes, which slowly but speedily increase in hardness, and the alumina cements, which reach max. strength in a few days. The tensile strength of high-alumina cement, or "alcement," is low compared with the compressive strength. Alcement is highly resis. to sea-water and water contg. gypsum, but is less resis. to alkali sulphates, and it deteriorates under the action of acids. If it is mixed with other cements, or is superimposed upon concrete made with Port., disintegration occurs. Attention is therefore directed to the prodn. of high early-strength Port. cement. The compn. is so selected that the cement has a high lime cementation index (0.99 Newberry). Small quantities of iron ores may be added to facilitate sintering and to increase vol. stability. The finest pulverization and intimate admixt. of the ingredients are essential. On a 10,000-mesh 8–13% should remain, and on a 4900-mesh 2–6%. From 3–4% of gypsum should be added. Port. cements have thus been made, surpassing the tensile strength of alcement, and almost attaining the early-strength. The initial temp. influences the early-strength, an interval of 5° lowering it by 10% after a 2-day test. H. H. S.

Mortar strength, a problem of practical statistics. J. W. GOWEN, H. W. LEAVITT AND W. S. EVANS. *Proc. Nat. Acad. Sci.*, **11,** 11–6(1925).—Seven-day and 28-day tests were conducted according to the standard A.S.T.M. procedure on 478 Maine sands in tension and 166 in compression. The following relations were developed between the 2 tests:

Tension (lbs.)	$T_{28} = 1.06\ T_7 + 51.5$
Compression (lbs.)	$C_{28} = 1.128\ C_7 + 793$
Tensile Ratio	$T\text{-}R_{28} = 0.87\ T\text{-}R_7 + 5.6$
Compressive Ratio	$C\text{-}R_{28} = 0.49\ C\text{-}R_7 + 50.7$

Predictions of the 28-day test may be made from the 7-day test by these formulas. As a margin of security, a definite lower limit in strength may be calcd. from the following table, which is obtained according to the theory of error from the standard deviation of the actual 28-day test. *Tension.* 50% of the tests will be above T_{28}; 75% above

T_{28}-29; 90% above T_{28}-55; 99% above T_{28}-100 lbs. *Compression.* 50% will be above C_{28}; 75% above C_{28}-416; 90% above C_{28}-801; 99% above C_{28}-1447 lbs. *Tensile ratio.* 50% will be above T-R_{28}; 75% above T-R_{28}-11.7%; 90% above T-R_{28}-22.6%; 99% above T-R_{28}-40.8%. *Compressive ratio.* 50% will be above C-R_{28}; 75% above C-R_{28}-13.5%; 90% above C-R_{28}-26.1%; 99% above C-R_{28}-47.1%. H. H. S.

Recent developments in the cement industry. C. H. DESCH. *Jour. Soc. Chem. Ind.*, **44**, 166(1925).—The setting of wetted cement is due to the decompn. of the aluminates into colloidal alumina, and of tricalcium silicate into mono-calcium silicate and $Ca(OH)_2$ which last slowly crystallizes in a colloidal matrix. The Roman practice of adding "pozzolana," a decomposed volcanic ash found at Pozzuoli, to mixt. of lime and sand has given the name "possolanic materials" to subs. added to give increased strength to cements, and blast-furnace slags are now utilized for resistance to sea-water and to heat. "Cement-fondu," made from bauxitic clay, can be recognized by its high content of metallic iron. Owing to its low silicate content, it reacts quickly with water and is favored as a road surface mat. H. H. S.

Testings on the influence of frost upon concrete. K. HABERKALT AND K. NAEHR. *Z. Verein deutsch. Ing.*, **68** [47], 1232(1924). W. S.

Hydraulic binding agent. FR. MÜLLER. *Chem. Zentralblatt*, **2** [22], 2551(1924). W. S.

German research on high-alumina cements. C. R. PLATZMANN. *Rock Products*, **27**[19], 23–5(1924).—*Conclusion.* Aluminates high in CaO are quick-setting while those low in CaO are slow-setting, and hydration of the latter depends upon the formation of hydrated Al_2O_3 and hydro-Ca aluminates. The high initial strengths are ascribed to the formation of a large proportion of colloidal substances and completeness of the hydration of the aluminates. A table of compressive strengths is given together with chem. compn. and sintering temp. (*C. A.*)

PATENTS

Furnace for firing, agglomerating, etc., of lime, gypsum, cement, ores, etc. OTTO LEO BORNER (Zürich). Ger. Pat. 401,718, *Chem. Zentralblatt*, **2** [22], 2549(1924).—The fur. case is put in swinging movement. The mat. is placed on a spiral inside the casing and passes from the top to the bottom by swinging the whole fur. around the vertical axle of this spiral. The firing zone is provided in a section preceding the last one, thus forming a cooling zone in the last section of this spiral. W. S.

Cement composition. GEORGE WITTY. U. S. 1,529,228, Mar. 10, 1925. A cement compn. consisting of gypsum, coarse silica, dextrin, saw-dust, barium sulphate and barite.

Enamels

Study your fuel problem closely. R. M. ONON. *Ceram. Indus.*, **4** [2], 110(1925).—The relative advantages and disadvantages of coal, oil, gas and electricity as fuels in the enameling indus. are discussed. P. D. H.

Insulation increases furnace efficiency. E. B. PRENTICE. *Ceram. Indus.*, **4** [2], 110–1(1925). P. D. H.

Urges fair furnace comparison. A. D. DAUCH. *Ceram. Indus.*, **4** [2], 111–2 (1925). P. D. H.

Well-insulated doors boost furnace production. J. E. HANSEN. *Ceram. Indus.*, **4** [2], 112(1925). P. D. H.

New smelter and drier combination. ANON. *Ceram. Indus.*, **4** [2], 156(1925).—A double smelter is described in which the ground and cover coats are fritted, one at either end. P. D. H.

PATENT

Enamel for metals or earthenware. I. TRAUBE. Brit. 221,830, Sept. 14, 1923. Any suitable glazing mat. is formed into a thick mixt. with an aq. soln. of compds. which will form ppts. remaining insol. at fusing temps., *e. g.*, a soln. of K chromate and a soln. of $MnSO_4$ may be mixed with sep. portions of the glazing mat. and the masses thus formed applied superposed or side by side. Fe oxide, chrome green or the like may be used to produce mottled effects. (*C. A.*)

Glass

The binary system of metasilicate–silica. G. W. MOREY AND N. L. BOWEN. *Jour. Phys. Chem.*, **38** [11], 1167–79(1924).—An investigation of the m. p. relations in the binary system sodium metasilicate–silica. The raw mats. used were quartz and sodium carbonate. The mats. were mixed in the desired propn. and melted in platinum. When the glass appeared clear and free from bubbles it was quickly cooled. The results of the invest. are given in the table.

TABLE I

Designation	Analysis Na_2O	Analysis SiO_2	Mol% Na_2SiO_3	Mol % SiO_2	Melting point	Solid phase
2154A	50.40	49.44	99.23	0.77	1086.5	Na_2SiO_3
2330A	45.88	54.03	82.32	17.68	1031.0	Na_2SiO_3
2142A	44.92	54.93	79.27	20.73	1001.0	Na_2SiO_3
2115A	39.55	.....	63.42	36.58	863.0	Na_2SiO_3
2512A	37.83	.....	60.85	39.15	847.0	$Na_2Si_2O_5$
2144A	37.59	62.29	58.48	41.52	859.0	$Na_2Si_2O_5$
2510A	35.90	.....	54.29	45.71	871.0	$Na_2Si_2O_5$
2518A	34.04	.....	50.03	49.97	873.5	$Na_2Si_2O_5$
2414A	33.99	.....	49.91	50.09	873.0	$Na_2Si_2O_5$
2034A	33.26	.....	48.44	51.69	872.5	$Na_2Si_2O_5$
2411A	32.83	67.25	47.32	52.68	868.0	$Na_2Si_2O_5$
2530A	29.20	.....	39.97	60.03	831 0	$Na_2Si_2O_5$
2530B	27.32	.....	36.44	63.56	802.0	$Na_2Si_2O_5$
2530C	25.78	.....	33.27	66.73	830.0	High quartz
2520A	24.81	.....	31.99	68.01	841.0	High quartz
2429A	19.54	.....	23.55	76.45	1145.0	Tridymite
2429B	11.67	.....	12.51	87.49	1457.0	Tridymite
2431A	4.07	.....	5.12	94.88	1596.0	Cristobalite

A comparison was made of the systems formed by SiO_2 with the metasilicates of lithium, sodium and potassium. The metasilicates of these showed a uniform diminution of m. p. with increasing at. wt. Li_2SiO_3 mtg. at 1201°, Na_2SiO_3 1088 and K_2SiO_3 976°, their disilicate m. p. being respectively 1032°, 875°. The system Na_2SiO_3–SiO_2 is of a simple type with one compd., sodium disilicate $Na_2O.2SiO_2$ and no solid solns. The m. p. of Na_2SiO_3 is 1088° and the eutectic Na_2SiO_3–$Na_2O.2SiO_2$ is at 840°, 62.5 mol% Na_2SiO_3, 37.5 mol% SiO_2. $Na_2O.SiO_2$ has a congruent m. p. at 874° and its m. p. curve is characterized by an unusually flat max. The $Na_2O.2SiO_2$ quartz eutectic is at 793°, 35 mol% Na_2SiO_3, 65 mol% SiO_2. E. J. T.

Recuperation increases capacity of English tanks. F. W. HODKIN AND W. E. S. TURNER. *Ceram. Indus.*, **4** [2], 106(1925).—(Excerpt taken from a paper read before the Society of Glass Technology.) The air for combustion is prehtd. first by passage through the flues, the arches of which support the bottom of the tank, and which are superimposed on other flues through which the products of combustion pass in an

opposite direction. The air is prehtd. further by passage through the space between the false crown and the main crown of the fur. One advantage claimed for this type of fur. is the reduction in the cost of construction by the reduction of the excavation needed due to the absence of regenerators. Approximately .8 of a ton of coal is consumed by the producers and boilers per ton of finished glassware. Another unique feature of the tank is the double bridge which has 3 walls sepd. by cavities through which steam is blown for cooling the blocks. The life of the bridge blocks is very much longer. The bridge inspected had been in opern. without repair for 14 mos.

P. D. H.

Information on window glass tank block. JAMES L. CRAWFORD. *Ceram. Indus.*, **4** [2], 107(1925).—The sizes of tank blocks trued for an 8, 12, 15 and 18 in. wall are given. The window glass indus. usually uses blocks trued for an 18 in. wall. Dimensioned sketches show a "throat" block for the open bridge wall and a "floater" which is used instead of a "throat" in window glass tanks. Several oil-fired recuperative tanks are in use and working satisfactorily. As long as fire clay is used for lining tanks it is doubtful whether they can be insulated successfully at the mtg. end. P. D. H.

Innovations for making hot repairs. THOMAS B. HART. *Ceram. Indus.*, **4** [2], 107–8(1925).—The use of ports on the machine end of a continuous tank fur. is advocated. The design of furs. in such a manner as to permit of complete and separate control of the firing of the mtg. and mach. end is also advocated. A dividing arch leading the gas and air from the induction flues into the mixing chamber; slag pockets in each regenerator to prohibit the checkers from slagging up; and a manhole in the back of each regenerator to facilitate hot checker repairs are also points which are well covered in complete dimensioned drawings. P. D. H.

The conductivity of annealed and unannealed soda-lime glasses. M. J. MULLIGAN. *Trans. Roy. Soc. Canada*, **18** [3], 120–1(1924).—The condy. of annealed and unannealed soda-lime glass was found to exhibit a marked difference (approx. 200%). The condy. is the same kind of function of the temp. in both cases, so that the change in glass brought about by annealing is one of deg. rather than of kind. Determinations were made of the wts. of mats. that were electrolyzed into these glasses at 180°C from a molten anode (KNO_3 and $AgNO_3$). The amts. were approx. inversely proportional to the resist. of the glasses, but the depth of penetration of Ag ions does not bear out the assumption that there is a marked difference in the degree of ionization of the two glasses. The major factor in increasing resist. by annealing is a decrease in the mobilities of the ions. H. H. S.

The sorption of water by soda-lime glass. J. W. REBBECK AND J. B. FERGUSON. *Trans. Roy. Soc. Canada*, **18** [3], 122(1924).—The gas produced when soda-lime glass is electrolyzed under certain conditions was previously found to be derived from the sorbed moisture. Properly annealed tubes were found to yield little or no gas. A number of such tubes were exposed to moisture under a variety of conditions and then electrolyzed. In general the glass appeared to take up moisture from the air slowly, but if the exposure is continued for a very long time the gas-evolving property becomes entirely restored. Soaking the glass in hot water for some hrs. also restores the property. Washing the glass with distd. water, removing this water rapidly by pumping and then filling by distn. the glass tube with mercury and electrolyzing in the usual manner, caused a definite amt. of gas to form. The rate of evolution of the gas was, however, so slow that it seems reasonable to assume that even this small quantity was partly absorbed. This conclusion is in agreement with modern theories of adsorption which postulate that adsorbed films are very thin. H. H. S.

Glass melting furnaces. (Discussion, Jan. 21, of Soc. Glass Tech.) *Jour. Soc. Chem. Ind.*, **44**, 169–70(1925).—The subject was introduced by papers from

J. S. ATKINSON and T. TEISEN. A. described the Stein recuperative pot furnace, the Unit pot furnace, the Torpedo tank and continuous leers. T. discussed the cross flame regenerative tank fur., comparing it with the open-hearth steel furnace. He opined that in small and medium-sized tanks, high thermal efficiency may be attained by use of the recuperative type. He proposed an all-steel accessible bridge cooled by water so that the molten glass should freeze round it and form a glass bridge. H. H. S.

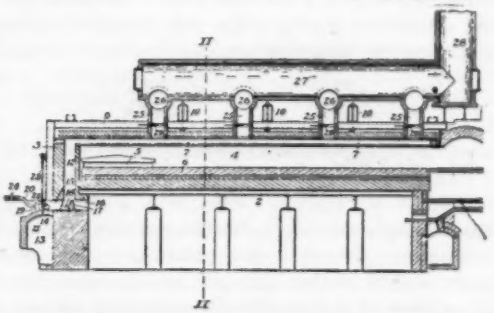
Silvering glass. A. STETTBACHER. *Tech. Ind. Schweiz. Chem.-Ztg.*, **1924,** 165–6.—S. gives a practical glassworker's recipe for silvering which appears to give very certain results. The distinguishing feature appears to be that only a "few drops" of the reducing soln. are used. (*C. A.*)

Joint committee for the standardization of scientific glassware. *Chemistry & Industry*, **43,** 913–5(1924).—In their report the Comm. unanimously recommended the *liter* (*l*) and *milliliter* (*ml*) as the standard units of vol., and that standard volumetric glassware be graduated in terms of these units and marked *ml* instead of *cc*. Reasons in support of the decision are given at some length. (*C. A.*)

PATENTS

Glass. Coating processes. A. S. CACHEMAILLE. Brit. Pat. *Oil & Color Trades Jour.*, **67,** 618(1925). Siliceous or vitreous articles, such as elec. light bulbs, are given an insol. coating by applying a prepn. contg. a sol. silicate, htg., and applying a neutral fixing soln. of an ammonium salt which reacts with the prepn. to form an insol. compd. The prepn. may comprise kaolin, pigments, and sodium or potassium silicate, which may be applied by spraying or dipping. The article is heated to 150°C for about 2 min., and then preferably dipped into a hot (75–115°C) saturated soln. of ammonium chloride or sulphate, whereby silica is pptd. The article is finally washed and dried. Instead of applying the fixing soln. hot, it may be applied cold, and the article subsequently reheated. O. P. R. O.

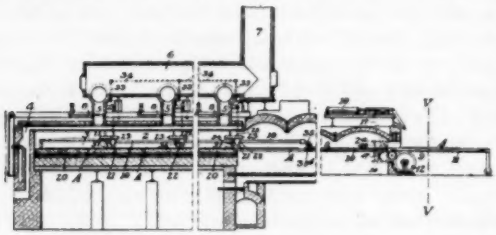
Plate-glass-annealing leer. EDWIN E. MILNER and WILLIAM J. LYTLE. U. S. 1,530,190, March 17, 1925. An annealing leer having a muffle chamber at the oven end and a leer end in line with the muffle chamber and communicating therewith, the top wall of the muffle chamber having therein a plurality of longitudinally extending heating flues, substantially as described.



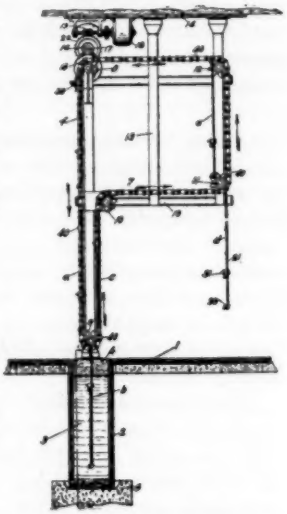
Glass pressing and blowing machine. EDWARD MILLER. U. S. 1,529,661, March 17, 1925. In a mach. for pressing and blowing glass vessels, the combination of a plurality of neck ring molds each composed of horizontally closable sections, a plurality of coöperating body molds each composed of independently horizontally closable sections, a plurality of vertically movable parison molds each adapted to coöperate with a neck ring mold to form a parison, a horizontally slidable carrier for each of said parison molds, a body mold bottom also mounted on each of said carriers and means for automatically shifting said carrier to place one of the parison molds into position for projection into coöperating relation with the sections of one of the neck ring molds and a body mold bottom into coöperating relation with the sections of the body mold of another neck ring mold.

Leer. SAMUEL A. FORTER and ADOLPH H. MEYER. U. S. 1,529,177, Mar. 10, 1925. The combination with a plate glass annealing leer having longitudinally re-

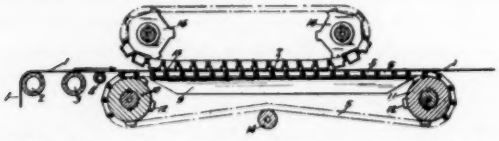
ciprocable pulling rods and vertically movable lifting rods, of mechanism for feeding the glass plates onto said rods, said mechanism comprising longitudinally extending pusher rods operatively connected to said pulling rods to reciprocate therewith and having depending pushing devices, together with means for automatically raising said pushing rods in unison with the lifting rods to permit the return movements thereof, substantially as described.

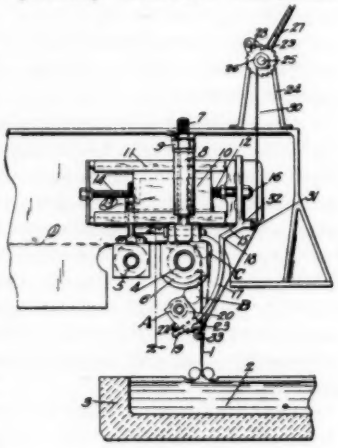


Apparatus for dipping sheet glass. ROBERT P. CALLARD. U. S. 1,529,239, Mar. 10, 1925. In an app. for dipping sheet glass, a tank containing a liquid bath, an endless conveyor, and a series of individual sheet carriers suspended from the conveyor and successively lowered into and raised from the bath as the conveyor moves above the tank, each carrier comprising an upright frame structure, a lower grooved member for supporting the lower edge of the sheet, and an adjustable latch for engaging the upper edge of the sheet.



Flattening table for continuous sheet glass. JOHN L. DRAKE and LEWIS D. BLACKSHERE. U. S. 1,529,243, Mar. 10, 1925. A drawing and flattening table for sheet glass, comprising in combination a pair of rotary cylindrical drums, a stationary table positioned between the drums and having a flat upper supporting surface, and a flexible link belt adapted to travel around the drums and over the table, the belt consisting of a plurality of pivotally connected links, each link having a flat upper sheet-supporting surface, and a lower surface of such conformation that the pivot centers of the links will be the same distance from the cylindrical link-supporting surface of the drums, while on the drums, as these centers will be from the flat link-supporting surface of the table, while on the table.

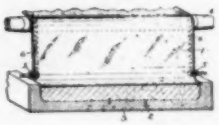




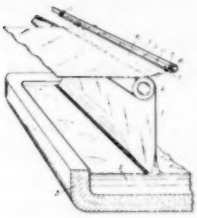
Glass. FRED M. LOCKE and FRED J. LOCKE. U. S. 1,529,259, Mar. 10, 1925. A glass having a low silica content, a high alumina content, the qualities of transparency and high elec. insulation under heat, and contg. an alk. earth oxid.

Changing bending rolls in sheet-glass-drawing machines. JOSEPH M. NEENAN. U. S. 1,529,268, Mar. 10, 1925. An app. for changing bending rollers in a machine for drawing a continuous sheet of glass and deflecting the plastic

sheet about a bending roller, comprising an auxiliary sheet-supporting roller, a pair of guides, one at either side of the machine, each guide extending from a point above and outside of the bending angle of the sheet to a point below and inside of this angle, a bearing for an end of the auxiliary roller movable along each guide, and means for simultaneously moving the bearings so that the auxiliary roller is carried from a position within the sheet angle and out of contact with the sheet, to a sheet-supporting position, the sheet being simultaneously lifted from the bending roller.



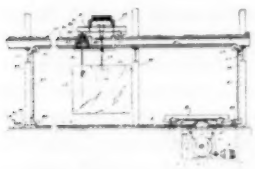
Bending roller for drawn sheet glass. JOSEPH A. REECE. U. S. 1,529,274, Mar. 10, 1925. In an app. for drawing sheet glass, a roller about which the sheet is deflected from one plane to another, the roller comprising sep. end and central portions adapted to travel at different peripheral speeds.



Reheating burner for sheet glass. JOSEPH A. REECE. U. S. 1,529,275, Mar. 10, 1925. In a sheet glass forming apparatus, a rehtg. burner comprising a gas pipe having a longitudinal series of openings in one side, a mixing chamber covering the openings and having a narrow slot in its outer portion opposite the series of openings, and air inlet openings in one side wall of the chamber, and an adjustable valve plate over the air inlets.

Sheet-glass-drawing apparatus. CLIFFORD A. ROWLEY. U. S. 1,529,278, Mar. 10, 1925. In app. for drawing a continuous sheet of glass from a pool of molten glass, a bending system for the plastic sheet comprising a plurality of rollers, the one about which the sheet is first deflected having a continuously curved sheet-carrying surface which is of larger diam. adjacent the ends of the roller than at the central portion thereof.

Glass-transfer apparatus. JOHN H. FOX. U. S. 1,529,584, Mar. 10, 1925. In combination in a system for surfacing sheet glass, having a track with cars or tables on said track and means for moving the cars along the track, a plate glass transfer and laying frame mounted above the track for movement longitudinally thereof, mech. connections driven from said means for moving the cars, adapted to shift said frame forwardly with the cars at the same rate of speed as the cars, and a motor for giving the frame a movement longitudinally of the track at a higher rate of speed than said movement of the cars.



"Splinterless" reinforced glass sheets. J. COX. Brit. 221,552, June 8, 1923. In sealing a sheet of cellulose acetate between sheets of glass, the glass is preliminarily treated with a soln. which may be formed of gum kornifan 28 g., nelkin oil 0.5 cc. (to prevent ropiness) and H_2O 112 cc. and the cellulose acetate sheet is treated with $C_2H_2Cl_4$ and HOAc. The sheets are then united under slight pressure at a temp. of about 40° and may be sealed with a cement formed of $CaCO_3$ 75 and boiled linseed oil 25 parts colored with ivory black or other pigment. *(C. A.)*

Heavy Clay Products

Brick making at the National Capital. ANON. *The Clay Worker*, **83** [1], 24–8 (1925).—The plants are described of the Wash. Hydraulic Press Brick Co.; Wash. Brick and Terra Cotta Co.; West Brothers Brick Co.; and Va. Brick Co. P. D. H.

Timely advice on firing. ANTON VOGT. *The Clay Worker*, **83** [1], 30–1(1925).—The use of draw trials is advocated to det. the end of the watersmoking period; the end of the oxidation period; and the finish of the firing. The method of holding the heat

in the top of the setting by means of draft regulation without overfiring the ware around the bag walls or on top is described fully. The manner of firing to obtain better colored brick or tile is also described. P. D. H.

Fundamental principles in the design of brick and tile as units of structural masonry. FRED T. HEATH. *The Clay-Worker*, **83** [3], 240–3(1925).—The three primary elements to be considered, namely, propn., bond and size, as well as their relationship to each other, are discussed in detail, primarily from the view-point of the builder. For the most efficient design of masonry work, it is shown, with sketches to illustrate, that the basic wall dimensions of the masonry units should conform to common units of measurement. The unit of 4 inches is suggested as a common basic standard because most all masonry forms already very nearly conform to it. P. D. H.

How brick are made in Chicago. ANON. *Brick & Clay Rec.*, **66** [2], 108–16 (1925). P. D. H.

The labor cost in common brick. ANON. *Brick & Clay Rec.*, **66** [2], 120–2 (1925).—Tables are given showing time required and cost in labor of producing soft mud, stiff mud and dry-press brick. P. D. H.

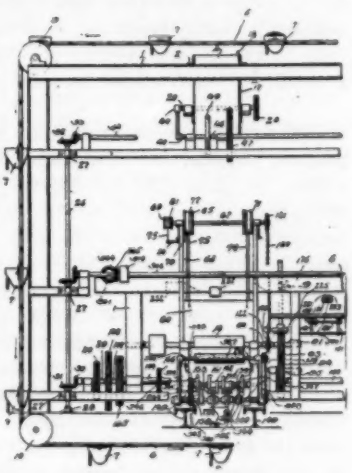
How whitewash can be prevented. H. C. MEYER. *Brick & Clay Rec.*, **66** [2], 128(1925).—The causes of scumming are given and a method of testing for soluble sulphates is outlined. The barium carbonate treatment for the prevention of whitewash or scum is considered the most reliable. Natural barium carbonate is quite as satisfactory as pptd. barium carbonate and is considerably cheaper. P. D. H.

Brick plant economy. D. D. OMUNDSON. *Contract Rec. and Eng. Rev.*, **39**, 172 (1925).—(Paper read at Can. Nat. Clay Products Assn.). How utilization of waste heat saves money in a brick plant. The experience of Citadel Brick Ltd., Quebec city: in five years the equipment and its operation were paid for and $58,000 was saved in the cost of fuel. Experiment demonstrated possibilities of using the heat of a cooling kiln to help another kiln along in the early stages. A waste heat drier was built and all kilns were connected together in such a manner as to permit drying and watersmoking with clean waste ht. and preheating the kilns with combustion gases at high temp. The average distance from the kilns to the waste heat drier is 350 ft. Part of the flue passes over a continuous kiln where it is buried in the filler over the chambers and beneath the firing floor. The flue being divided in order to get sufficient volume, provision was made for picking up all available waste heat from the cooling chambers of this kiln by using special goosenecks. While some plants have experienced cracked ware, with the use of waste heat in drying, due probably to increased humidity where the green ware enters, usually bricks come through in better condition and with less loss than in radiated heat tunnels. The drier is a standard waste heat drier, the induction fan discharging into the tunnel under the car track, the openings going back about half the length of the tunnel and a control damper located at the door of each tunnel. Watersmoking is done with the clean heat of a cooling kiln, and while temp. is seldom over 400°F during this period, the intense draft seems to carry away all traces of moisture. From 24 to 36 hrs. of this treatment has been found to be sufficient, after which the combustion gases of another kiln are used to raise the temp. to as high as 700°F. Thus all the low temp. work is carried on under a comparatively high vacuum without the expenditure of fuel and without damage to the ware. The actual firing time varies from 68 to 84 hrs., depending on the fuel used, size of kiln (these kilns described are 30 and 32 ft.) and the result desired. This compares to the $8^1/_2$ and 9 days firing time per kiln before installation of these special waste heat driers. In decarbonizing a kiln before raising the temp. to finishing heat the strong induction is of great use in speeding up this process. The rapid turn-over of kilns is one reason for fuel economy, on account of the shorter radiating period. There has not been a case where

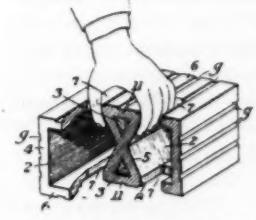
application of these principles of operation has been applied intelligently that any previous established standards of excellence were not only equaled but surpassed, in as much as invariably the induced draft increases the percentage of No. 1 ware. The cost of installing the means to effect changes on a battery of kilns already in existence would vary according to plant layout and local conditions but as an approx. figure, where conditions are not unfavorable and drainage has been previously provided, the cost should be about $1200 per kiln (32 ft. diam. kiln), exclusive of fans and motors, which should cost approx. $5000 for a battery of 9 kilns and a waste heat drier. The cost of these features when building a new kiln would be much less than installing them in old kilns. In trying to det. whether or not it is profitable to effect the changes that provide control of your waste heat it is only fair to remember that the productive capacity of the kilns is increased 50%, due to the changes as outlined. O. P. R. O.

PATENTS

Machine for and method of making brick. ROY P. M. DAVIS and IRVIN F. HEPLER. U. S. 1,529,692, Mar. 17, 1925. A brick making mach. comprising a frame, having a hopper therein, means for feeding mud to the hopper, said hopper having gates therein for trapping the mud fed to the hopper, a mold support mounted for oscillatory movement in said frame, an open ended mold carried by the mold support, movable splash plates mounted in the frame adjacent the mold support, means for oscillating the mold support to bring the mold into alinement with said hopper, and means for simultaneously opening the plates of the hopper and for moving said splash plates to operative position. The method of making brick consisting in forming a brick in a mold, mechanically ejecting the brick therefrom, and then subjecting the ejecting means to a rotating shifting brushing action to clean adhering material from the ejecting means.



Hollow tile. HENRY J. F. LUDEMAN. U. S. 1,529,317, Mar. 10, 1925. A hollow tile having horizontal longitudinally extending voids defined by side and intermediate load carrying walls, said tile having substantially centrally located supplemental openings in overlapping side by side parallel relationship intersecting said voids and forming hand receiving holes, each of said openings having its major axis parallel to the longitudinal axis of the tile, substantially as described.



Process of coloring clay articles. EUGENE L. CHAPPELL. U. S. 1,528,401, Mar. 3, 1925. A process of coloring brick and the like, consisting of passing in contact with the cooling brick, the gasified atmosphere which has passed from the htg. and prehtg. brick.

Manufacturing of light brick. A. G. BREMEN. Ger. Pat. 401,866. *Chem. Zentralblatt*, **2** [22], 2551(1924). To the slip made of water and small pieces of peat 50% CaO and gypsum are added to destroy the colloidal structure of the peat. During slaking the CaO, the stone remains in a mold under high press. in order to reduce the expansion. The ware is light, cheap, insulating and sound-proof. W. S.

Refractories

Suggestions on boiler furnace design. C. M. GARLAND. *Power*, **61** [5], 176 (1925).—Fur. temp. is intimately related to the combined efficiency, the capacity developed, and the life of the fur. lining. The highest temp. possible consistent with reasonable refrac. life should be maintained. All heat transactions occurring within the fur. and boiler setting will be dependent upon high temp. for the greatest efficiency, and the only limit at the present time is the life of the refracs. Too long life to the refracs. indicates uneconomical operation. Radiation and conduction losses are discussed together with losses caused by stratification of gases and the proper type of stoker to prevent stratification. C. J. H.

Water-cooled furnaces. H. D. SAVAGE. *Mech. Eng.*, **47** [3], 197(1925).—Fur. linings and refracs. have not been keeping pace with the studies being made in other features of power plant development. Higher settings, higher ratings and higher efficiencies now being made have placed a duty upon boiler fur. that cannot be met satisfactorily by the refracs. available, or of common or standard use. This has led to (1) hollow-wall refrac. furs.; (2) steam-cooled walls; (3) water-cooled walls. The completely water-cooled fur. or a combination of water-cooled and refrac. fur. would seem to present the greatest possibilities for future interest. The author deals with a number of water-cooled furnaces of the finned type, or as it is now called, fin. fur. C. J. H.

The relation between ordinary refractoriness, under-load refractoriness, and composition, physical and chemical, of refractory material. Pt. 1. A. J. DALE. *Trans. Ceram. Soc.* (Eng.), **23**, 217–33(1924).—In htg. fire clay brick made with fire clay grog under constant load with steadily increasing temp., the temp. at which subsidence commences is independent of the grog content. With various brick there is a variable range of temp. between the commencement of subsidence and the point of complete failure. The temp. at which complete breakdown occurs is lower with grogged brick than with straight clays. When grogged brick were tested under load at constant temp., 1350°C, it was found that the greater the propn. of grog, the more rapid the subsidence and the greater its amt. H. F. S.

The influence of texture on the transmission of heat through firebricks. A. T. GREEN. *Trans. Ceram. Soc.* (Eng.), **23**, 253–70(1924).—The harder the firing of clay brick the lower the true sp. gr. and the higher the conductivity. Decrease in porosity by any means causes increase in the thermal condy. H. F. S.

The thermal conductivity and some other properties of two commercial heat insulating brick used in kiln construction. A. T. GREEN. *Trans. Ceram. Soc.*, **23**, 271–6(1924).—One batch of brick was made by mixing diatomaceous earth with 15% of cork and sawdust and firing to 890°C. The other was made by mixing diatomaceous earth with 15% sawdust and 10% clay and firing to 890°C. The second brick had much the greatest mech. strength. The thermal condy. was slightly higher. The condy. of these brick was about $^1/_4$ that of fire clay brick at temp. about 500°C. H. F. S.

Graphite in Nyasaland. ANON. *J. Soc. Chem. Ind.*, **44**, 219(1925).—Flake graphite which has been worked in Nyasaland is reported by the Brit. Imperial Inst. to be of excellent quality, equaling the best grades of the Ceylon mineral. H. H. S.

Interesting facts about refractories. FRED A. HARVEY. *Fuels and Furs.*, **2** [4, 5, 6, 7, 8], Apr. to Aug. (1924).—The first paper deals with silica brick; sources of raw mat., compn., mfr., props., density, softening point, strength, porosity, sp. ht., therm. condy. and expansion. Diff. between permanent expansion on firing and subsequent htg., which is reversible, is noted. The second article deals with fire clay brick in same manner with the addn. that, under properties, slag action, spalling and abrasion

are here given. The third article deals with silica, fire clay and spec. cements. Dangers of adding too much fire clay to grd. silica bat, which greatly lowers the fusion point, are pointed out. Methods of raising the fusion point by finer grinding and decreasing fire clay content, as well as subst. raw ganister for a part of the silica bats are mentioned. For fire clay brick a mixt. of 20 to 30% calcined clay grd. with 80 or 70% raw clay of same compn. as the brick makes best cement. Use of "black strap" molasses for obtaining a hard cement without lowering the fusion point, is also mentioned. Part IV is a discussion of the mfg. and props. of magnesite, silicon carbide, aluminous refrac., alundum, dolomite, diatomaceous earth and zirconia. Part V deals with the testing of refrac. A gen. discussion of the three classes of "failures" and suitable tests is followed by concise directions for sampling, inspection, how to judge silica brick and shapes, vol. change on re-htg., softening point, d., load test, crushing and mod. of rupture, spalling, slagging, abrasion, condy., fineness and plasticity. Altogether a very interesting and complete series of articles on this subject. R. D. L.

Refractory industry in Canada. W. G. WORCESTER. *Contract Rec. and Eng. News*, **39,** 111(1925).—Saskatchewan clays particularly are being developed with remarkable success. It is only recently that the possibilities of the refrac. clays of Sask. have been known. The important refrac. clay deposits in Canada are those at Clayburn, B. C.; those at Dirt Hills, S. Sask., and the siliceous kaolinite deposits at St. Remi, P. Q. In Sask. there is evidence to warrant the assumption that the deposit is very large. Development work has progressed materially. The Canadian Pacific and the Canadian National Railways have installed the Sask. products on a number of their locomotives, first in conjunction with imported arch tile and later, through the findings of the first tests, they had no hesitancy in sending out locomotives equipped completely with Sask. tiles. Results have been most satisfactory; in some cases the local tiles have outlasted imported tiles by many thousand miles service. Hand molded and machine made wares have been made which have entered into direct competition with imported wares. O. P. R. O.

Refractory materials for constructing hearths and coke-ovens. W. SOHERR. *Glückauf*, **60,** 1055–63(1924).—A review of the phys. chemistry of the behavior of refrac. including the system CaO–SiO_2–Al_2O_3, which in itself suffices to explain the behavior of most materials. Silica stone prepd. by adding milk of lime to quartzite shows, in the form of thin sections, the individual metamorphic forms of silicic acid, quartz, tridymite and christobalite. By this means the quality of the stone can be judged. (*C. A.*)

Silica brick and its manufacture. H. SCHILLING. *Chem.-Ztg.*, **49,** 6–7(1925).—The refractoriness of silica brick depends upon the network of tridymite crystals formed in the firing to cone 15. Microscopic methods furnish the only reliable means of testing since chem. analysis is useless. Too coarse a structure in the quartzite is undesirable because of difficulties of soln. in the flux (CaO) and crystallizing out as tridymite. The CaO plays a double rôle: (1) it acts as a flux, forming the matrix from which the pseudo-hexagonal tridymite crystals form and (2) the Ca silicate acts as a binder. The MgO content of the fired CaO should not exceed 5%, because the consequent increase in viscosity hinders the formation and crystn. of tridymite. The purer the CaO, the better. (*C. A.*)

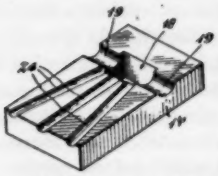
PATENTS

Kaolin refractory and process of making the same. ISAAC HARTER and ANTHONY M. KOHLER. U. S. 1,530,260, March 17, 1925. A refractory article consisting of particles of kaolin fired at a temp. of not less than 3000°F and bonded with kaolin.

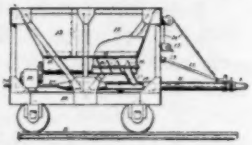
Art of manufacturing zirconium compounds. LONNIE W. RYAN. U. S. 1,530,139, Mar. 17, 1925. The method of mfg. zirconium compds. which comprises decomposing

a siliceous zirconium ore with not more than twice its weight of sulphuric acid, neutralizing the free acid in the resulting soln., pptg. a granular basic zirconium sulphate from said soln. and sepg. the pptd. granular basic sulphate.

Fire brick for furnace walls. CHARLES D. HOWREN. U. S. 1,529,183, Mar. 10, 1925. A fur. wall and the like having vertical and horizontal air channels, said wall being formed of fire brick having transverse openings intermediate the ends thereof forming the vertical air channels, and transverse surface grooves connecting the said openings and forming the horizontal air channels, said brick also having surface grooves extending in the direction of their lengths, the latter grooves outletting through one end of the brick and communicating at their opposite ends with said air channels.



Making open-hearth-furnace bottoms. HARRY M. SCHAAB. U. S. 1,529,219, Mar. 10, 1925. The method of making open hearth fur. bottoms which consists in directing a stream of gaseous fluid into the fur. and against the portion of the fur. which is to be repaired from a point outside the fur., and introducing crushed dolomite to the stream while maintaining a dolomite fusing heat in the fur., the dolomite being introduced to the fluid stream in such manner that all particles of the dolomite will be immediately subjected to the action of the fluid stream, substantially as described.



Refractory material. DYNAMIDON-WERK ENGELHORN & CO., GES. Brit. 221,799, Sept. 14, 1923. Burnt magnesite or MgO contg. little or no flux is finely ground, pressed and sintered at 1500–1600°. The MgO may be hydrated before sintering and the sintered material is crushed and may be used as a mortar or for making brick. Clay, starch or tar may be added to facilitate molding and fired or hydrated magnesite 5–10% may be added to the sintered material. Cf. *C. A.*, **18**, 1889. (*C. A.*)

Refractory compositions containing zirconia. G. KALLEN. Brit. 221,852, June 12, 1923. Refractory articles are made by firing a mixt. of crude Zr ore and a plurality of different binding ingredients which soften progressively with increase in temp. such as water glass, glass of low m. p., dolomite, feldspar, port. cement, magnesite, clay or bauxite; *e. g.*, Zr ore 88, dolomite 9 and feldspar 3 parts are mixed with a 3% water glass soln., molded and fired at about 1000°. A fireproof paint is formed from Zr ore 40, water glass 20, dolomite 20, casein 5 and H_2O 20 parts. (*C. A.*)

White Ware

Investigations leading to the discovery of the cause of excessive sagger breakage. W. STEGER. *Trans. Ger. Ceram. Soc.*, **5**, 3(1924).—Three main causes are (1) use of unsuitable raw mats. and unfavorable batch composition; (2) imperfect prepn. of the batch; (3) improper firing. This article only covers investigation under (1) and by detg. and charting the thermal expansion in 4 temp. zones between 20° and 750°C of clays varying in free silica content between 3% and 73% the critical periods of quartz and cristobalite inversion are clearly shown. The rapid expansion of the clays high in free SiO_2 naturally leads to lowered resist. to temp. changes and it is therefore important that in the initial firing all the free SiO_2 is taken into soln. The tests brought out that all clays contg. free SiO_2 have certain critical temp. ranges in which they are more susceptible to temp. changes on acct. of the changes of the quartz to other forms. The extent of the volume changes involved is dependent on the grain size and crystallic nature of SiO_2 bearing mat., the finer the grain the greater the change in vol. Mats. suggested to take the place of quartz are mat. with high alumina content, carborundum and natural sillimanite. F. A. W.

The influence of grain size on the solubility of quartz in feldspar in porcelain fire. KURT WETZEL. *Trans. Ger. Ceram. Soc.*, **5**, 2(1924).—Quartz grains of uniform size are dissolved at a uniform rate by melting feldspar. In the series potash spar–quartz the soly. of the coarsest grained quartz used was 95% rising gradually to 100% for the finest grains. If a mixt. of grains is used the finest will be completely dissolved and the coarser ones only partially. Practically no difference in soly. was noted between Hohenbocka sand and Norwegian quartz. Different grades of feldspar showed more marked variation. Norwegian feldspar has a higher soly. than soda feldspar from N. Bavaria. Addition of strong flux such as lime or magnesia increases the soly. A comparison between the soly. of feldspar and a porcelain body showed close similarity.

F. A. W.

Changes in a porcelain body during firing. R. RIEKE. *Trans. Ger. Ceram. Soc.*, **5**, 5(1925).—Trial pieces measuring 2 x $1^1/_4$ x $^3/_8$" were made from a hard porcelain body with a rational anal. approx. 55% clay subs., 25% quartz, 25% feldspar. These were fired in a commercial porcelain kiln to Seger cone 15 in 36 hours and drawn at intervals of 50°C. Both unfired and previously biscuited pieces were tested. Changes in shrinkage, porosity and sp. gr. are governed by the behavior of the clay subs. at temp. below the m. p. of the feldspar (1150–1200°C). Marked change in sp. gr. most noticeable around 940°C. Immediately after the feldspar has melted the formation of $3Al_2O_3.2SiO_2$ crystals commences and reaches its max. around 1375°, continuing during the cooling. A filling of the fine pore spaces of the mat. with carbon, etc. during the early stages of firing could not be detd. Further tests with a biscuited hard porcelain body No. 2 having a very high clay subs. and low quartz content showed a marked drop in % pore space between 950° and 100°C and then a lag until 1070°C followed by another sharp drop, reaching complete vitrification about 100°C earlier than body No. 1. This indicates that a suitable quartz content promotes a more gradual shrinkage

TABLE I

HARD PORCELAIN BODY NO. 1 (RAW)

No.	Temp. in deg. C.	Linear shrink. in %	Absorption in %	Sp. gr.	Porosity in vol. %	Loss on ignition	Color
1	460	0.52	22.1	.....	....	6.85	Dark gray
2	520	0.52	22.5	2.631	37.2	6.90	Dark gray
3	610	0.52	22.8	2.564	37.0	1.48	Light gray
4	665	0.52	24.5	2.570	38.6	1.17	Lighter than No. 3
5	715	0.52	24.6	2.572	38.7	0.88	Lighter than No. 4
6	765	0.52	24.9	2.593	39.3	0.67	Like No. 5
7	865	0.52	25.4	2.575	39.5	0.45	White
8	925	0.52	25.3	2.582	39.5	0.32	Very light pink
9	965	1.17	25.2	2.629	39.8	....	Very light pink
10	1025	1.30	25.1	2.636	39.8	....	White
11	1080	3.64	20.3	2.623	34.7	....	Slightly yellowish
12	1120	7.59	13.5	2.599	25.9	....	Slightly yellowish
13	1160	9.16	9.9	2.588	20.3	....	Yellow
14	1205	11.74	3.5	2.547	8.2	....	Grayish yellow
15	1250	12.56	0.2	2.499	0.4	....	Blue gray
16	1305	13.15	....	2.489	....	....	Blue gray
17	1350	13.08	....	2.471	....	....	Blue gray
18	1410	12.82	....	2.441	....	....	Grayish white
19	1410	12.04	....	2.451	....	....	White
20	Cooled in kiln	12.30	....	2.460	....	....	Yellowish white

TABLE II

HARD PORCELAIN BODY NO. 1 (BISCUITED)

No.	Temp. in deg. C	Linear shrink. in %	Absorption in %	Sp. gr.	Porosity in vol. %	Color
1	460	0.4	24.2	2.637	38.9	
2	520	0.4	24.4	2.638	39.1	
3	610	0.3	24.4	2.639	39.2	
4	665	0.3	24.4	2.635	39.1	
5	715	0.3	24.6	2.631	39.3	Pink
6	765	0.3	24.3	2.668	39.3	
7	865	0.3	24.1	2.634	38.8	
8	965	0.3	24.2	2.631	38.9	
9	925	0.3	23.8	2.639	38.6	
10	1025	0.6	23.7	2.641	38.5	
11	1080	2.78	19.6	2.620	34.0	
12	1120	6.32	13.5	2.605	26.0	
13	1160	7 18	10.9	2.588	22.0	
14	1205	9.55	4.8	2.531	10.9	
15	1250	10.84	0.2	2.495	0.4	Same as Table I
16	1305	11.20	0	4.484	0	
17	1350	9.68	....	2.474	....	
18	1410	9.85	....	2.551	....	
19	1410	9.16	....	2.454	....	
20	Cooled in kiln	9.16	....	2.461	....	

TABLE III

HARD PORCELAIN BODY NO. 2 (BISCUITED)

No.	Temp. in deg. C	Linear shrink. in %	Absorption in %	Sp. gr.	Porosity in vol. %	Color
1	540	0.3	24.8	2.557	38.8	
2	640	0.0	24.5	2.566	38.6	
3	700	0.3	24.4	2.572	38.6	Pink
4	755	0.3	24.8	2.564	38.9	
5	825	0.3	24.7	2.574	38.9	
6	905	0.4	24.1	2.555	38.1	
7	950	1.2	24.2	2.621	48.8	
8	980	1.6	18.9	2.637	33.3	
9	1020	1.9	18.0	2.633	32.2	White
10	1070	3.6	18.6	2.622	32.8	
11	1090	5.9	12.3	2.603	24.2	
12	1120	10.5	5.6	2.580	12.6	Yellow
13	1150	12.3	0.2	2.520	0.5	Gray
14	1180	12.0	0.2	2.523	0.5	
15	1210	12.4	0.0	2.518	0.0	
16	1250	13.0	....	2.527	....	Bluish gray
17	1300	13.4	....	2.515	....	
18	1350	13.5	....	2.524	....	Grayish white
19	1400	12.9	....	2.509	....	White
20	Cooled in kiln	11.6	....	2.530	....	Yellowish white

and vitrification and thereby lessens the danger of warpage. Tables I, II and III show comparative results. F. A. W.

Improperly pugged clay and its effect on: (a) The wage earning capacity of the operatives; (b) the loss of defective ware to the employers. ARTHUR HOLLINS. *Trans. Ceram. Soc.* (Eng.), **23,** 157–75(1924).—H. spoke as representative of the National Society of Pottery Workers. Vertical pug mills produce clay that is not so consistent or homogeneous as clay from horizontal pug mills. Pugging rolls, such as are used on the Continent, produce the best pugged clay but their output is limited to 250 pounds every 25 minutes. For rapid working and a good final product, the pugged clay should be uniform in consistency (hardness), plasticity, and homogeneity (closely allied to consistency but including elimination of air bubbles). The pugged clay given to various classes of workers should be of proper consistency for that particular work. Improperly pugged clay may be too hard or too soft, may contain both hard and soft clay, may contain air bubbles. These defects slow down working and reduce the operators wages. They also reduce the employers profits. Non-uniform sizes in finished ware, due to variation in water content of pugged clay, cause difficulties in fitting decorative patterns and reduce transferrers wages. Too soft clay reduces the life of molds by causing a pin-holed surface. Clay that is too wet produces pin-holed ware. Clay should be stored after pugging. Water should never be added at the pug mill. If clay has become too dry it should be re-blunged. The pugging of clay should be in the hands of more intelligent men than is commonly the case. H. F. S.

The discovery of china in Europe. J. W. MELLOR. *Trans. Ceram. Soc.* (Eng.), **23,** 179–81(1924).—In 1709 J. F. BÖTTGER, a German apothecary apprentice, working in the Disden Laboratory of Augustus the Strong, King of Poland, first made true hard porcelain in Europe. In France in 1765, MME. DARNET, the wife of a medical man of St. Yrieix near Limoges, noticed a white clay abundant in the community and sent it to a chemist to det. whether it could be used as a sort of natural soap. He identified it as a mixt. of kaolin and feldspar and this led to the French china indus. In England, WM. COOKWORTHY, a chemist, made an exhaustive search for china making mats. and finally in 1768 discovered suitable mat. at St. Stephens near St. Austell. He established 2 factories for making hard porcelains but this kind of manuf. was abandoned after a few years. However the mats. discovered by COOKWORTHY were used in other branches of ceramics. H. F. S.

Electrical porcelain: the effect of varying the composition upon some of its properties. ERNEST WATKIN. *Trans. Ceram. Soc.* (Eng.), **23,** 185–210(1924).—Substituting feldspar for flint reduces the maturing temp. of the body, producing a more glassy structure, which has a higher sp. gr., but which is weaker mechanically. The sp. elec. resist. is decreased, but the dielec. strength is increased. This evidence disproves any relationship between the sp. resist. and dielec. strength. Substituting clay for flint increases both the dielec. strength and sp. resist., but reduces the mech. strength. Substituting ball clay for china clay has a deleterious action on all properties investigated, elec. and mech. Substituting red clay for china clay reduces slightly both the dielec. strength and sp. resist., also the mech. strength. Substituting zirconium silicate for flint greatly increases the mech. strength, but has little influence on the elec. properties. Substituting steatite for feldspar increases greatly the sp. resist., but has little effect upon the dielec. strength or the mech. strength. H. F. S.

Note on alkaline casting slip. F. S. WORTHINGTON. *Trans. Ceram. Soc.,* **23,** 277(1924).—The amt. of contraction to which cast ware is subject in drying and firing is affected by the weight of solid matter per pint of slip, the greater the weight per pint the less the contraction. Ware cast with light slip is more liable to craze than ware cast with heavy slip. H. F. S.

Glaze defects on whiteware. A. SCHOBLIK. *Keram. Rund.*, **33,** 7–9(1925).—If the acid content of a glaze is too low it will not unite thoroughly with the body. If the acid content is too high there will not be sufficient basis to form a good glass. In the first case the glaze will either run from the body or else become absorbed by the body because of its low viscosity. Glazes contg. too much SiO_2 will develop matt glazes due to the crystn. on the surface which can be seen under the microscope. If the content of silica is too high the mtg. point of the same may often be increased sufficiently to cause small pits to remain upon the surface due to gases which have escaped through the glaze in firing. Too much whiting will also cause a crystn. of the glaze as well as small bubbles on the surface. This trouble can often be overcome by adding a small amt. of flint to the glaze. If too much flint is added needle-like crystals are formed on the surface of the glazes which contain both Ca and SiO_2. The crystals formed on the surface of glazes contg. too much BaO are entirely different from those formed with too much SiO_2 or CaO. A very good matt may be produced in this manner. Glazes contg. too much BaO are very susceptible to sulphuring. Strong oxidizing firing facilitates the combination of the S gases with the Ba in the glaze and a slightly reducing atmos. should be maintained to minimize this action. Underfired glazes often have a matt appearance not due to crystn. When these glazes are examined under the microscope they appear to be covered with many small air bubbles which give them the matt appearance. H. G. S.

Glazes in the ceramic industry. P. P. BUDNIKOFF. *Isvestia Ivanovo- Vosnessenskovo Politech. Inst.* (Russia), I, 87–97(1919).—The properties, compns. and methods of prepn. of various glazes for various substances are given, also methods of applying the glazes. J. S. J. (*C. A.*)

Equipment and Apparatus

Portable equipment for transverse tests of brick. H. D. FOSTER. *The Clay Worker,* **83** [3], 234–6(1925).—The app. as developed at the U. S. Bur. of Stand. is described. A detailed drawing from which it can be built is given. P. D. H.

Temperature-load determinations and their possibilities. HANS HIRSCH. *Trans. Ger. Ceram. Soc.*, **5,** 3(1924).—Describes tests made with a Steger lever press and a new app. developed in the "Laboratory for Clay Industries," Berlin. These both have a sensitive recording device. Small test pieces having a cross-section of 8 $cm.^2$ were used and heated in an elec. fur. with a temp. advance of 4–5°C per min. Pressures used were 1 kg. per $cm.^2$ for silica brick and 2 kg. per $cm.^2$ for clay brick. Numerous charts show the behavior of widely different refrac. bodies and kaolins. Those with increasing Al_2O_3 content showed a more gradual softening range. Refractories high in silica showed a preliminary expansion and then a rapid softening. Kaolin showed an irregular curve indicating a retardation in the softening at certain stages. F. A. W.

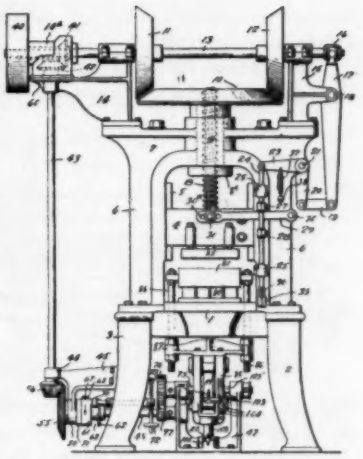
The quartz spectrograph in mineral analysis. E. W. TODD. *Univ. Toronto Studies, Geol. Ser.*, No. **17,** 66–8(1924).—The use of a spectroscope in qual. detn. of the elements present in a mineral, and in forming a rough est. of their abundance, is illustrated by several examples. (*C. A.*)

PATENTS

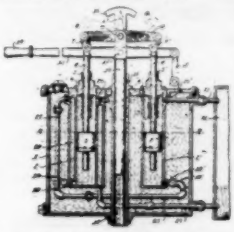
Device for measuring the specific gravity of material consisting of gravel. ULRICH TILLINGER (Charlottenburg). Ger. Pat. 399,080. *Chem. Zentralblatt,* **2** [14], 1845 (1924). The mat. is put in an air tight container in which the vol. of air surrounding the mat. can be changed. By changing the air vol. in the container the difference of the air press. indicates the sp. gr. of the mat. W. S.

Ceramic press and the like. HILMAR MUELLER. U. S. 1,530,053, Mar. 17, 1925. In a mach. of the character set forth, in combination with the plunger, die case and face

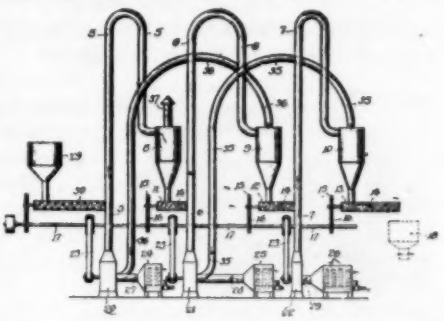
plate, friction means yieldingly sustaining the die case at any elevation to which it is moved, and power driven mechanism for raising and lowering the die case and so acting as not to interfere with the depression of the die case by the face plate during the pressing operation.



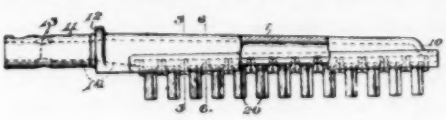
Viscosity comparator. LESLIE R. PRIEST. U. S. 1,529,811, Mar. 17, 1925. A viscosity comparator comprising a pair of receptacles respectively adapted to receive and contain a supply of standard liquid and a supply of the liquid to be compared therewith, each receptacle having associated therewith an orifice through which the liquid contained therein may flow, the areas of said orifices bearing a known relation to each other; means for producing press. in the liquids contd. within said receptacles to cause said liquids to flow through said orifices; a connection between the press. producing means of the two receptacles to cause the press. of the 2 liquids to bear a known relation to each other; and means for indicating the viscosity differential between said liquids as detd. by their comparative rates of flow through said orifices.



Method and means for treating material. PHILIP A. SINGER. U. S. 1,528,995, Mar. 10, 1925. In a treating system of the character described the combination of a series of treating pipes and cyclone collectors in alternate arrangement, the pipes being substantially vertically disposed throughout a materially large part of their respective lengths, one of said collectors being at the rear end of the system, each intermediate collector having means associated therewith for feeding finely divided mat. into the treating pipe next following in the direction of travel of the mat. through the system, means for introducing such mat. into the first pipe of the series, means for causing an aeriform treating current to flow in each of said pipes, and with a greater velocity in the first thereof, to carry such material to the collectors respectively, and means for conveying exhaust current from one of said collectors and discharging it into the system at a place ahead of one of said collectors.

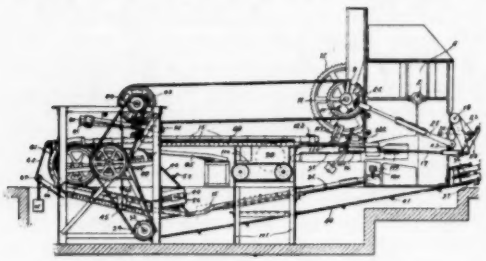


Rabble and rabble arm for metallurgical furnaces. LOUIS R. KELLEY. U. S. 1,529,256, Mar. 10, 1925. The combination of an arm having a channel opening laterally through one side of the arm, the side walls of the channel being oppositely directed to form supporting flanges, a plurality of members removably supported by said arm upon said flanges and substantially closing the otherwise open side of the channel, and

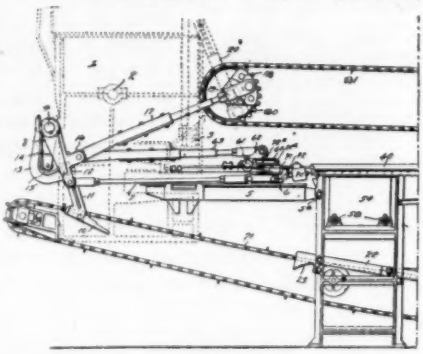


passageways formed in each of said members to permit air to pass therethrough from within said channel.

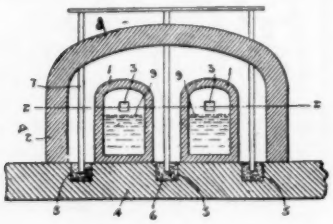
Mechanism for handling brick molds. DAVID J. STRICKLAND. U. S. 1,529,452, Mar. 10, 1925. In a brick mach., the combination with a pug mill adapted to fill a series of molds fed thereunder, of a pair of arms adapted to receive said filled molds and deliver them to a conveyor, a second conveyor for receiving said filled molds and upsetting them and means engageable with said molds before and after upsetting whereby the brick are loosened therein.



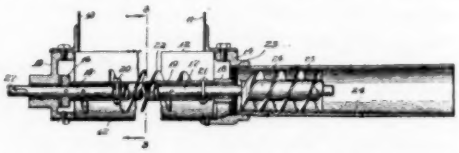
Brick machine. DAVID J. STRICKLAND. U. S. 1,529,453, Mar. 10, 1925. In a brick making mach., the combination with a reciprocating carriage, of a rock shaft carried by said carriage, mold receiving arms connected to said rock shaft, means for normally holding said arms elevated together with means for depressing said arms. In a brick making mach., a mold having an inclined rabbeted shoulder at each end thereof.

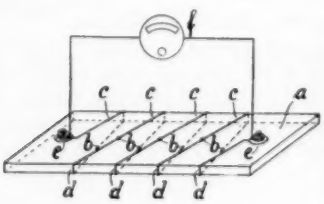


Glass furnace. ALLAN GRAUEL. U. S. 1,529,480, Mar. 10, 1925. In a glass fur. the combination with the closed fur. wall and foundation bed having channels formed therein, of glass pots placed between the channels, and an incandescent body contd. in said channels and radiating its ht. upward around the glass pots.



Method and apparatus for transferring dust. JOSEPH B. TAYLOR. U. S. 1,528,348, Mar. 3, 1925. Means for compressing dust to expel the air therefrom in a uniform and continuous manner, comprising screw conveyor and a slightly flaring tube surrounding the same and extending beyond the end of the screw.





Device for the measurement of heat. ERNST SCHMIDT. U. S. 1,528,383, Mar. 3, 1925. In a device for measg. the ht. flow from bodies, a member having flat surfaces, one surface of which is applied to the body, the ht. flow from which is to be measured, thermal-elec. means associated with the opposite surfaces of said member and adapted to respond to temp. differences between the surfaces

of said member, and means connected in series with said thermo-elec. means and calibrated to indicate the degree of said response.

Kilns, Furnaces, Fuels and Combustion

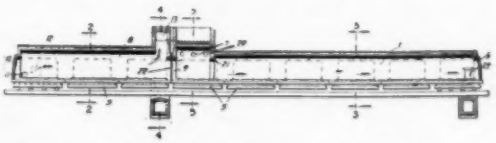
Oil burning and oil-burning equipment. W. F. SCHAPHORST. *Jour. Ind. & Eng. Chem.*, **17** [1], 5–10(1925).—A resumé of the uses of oil in chem. and ind. plants as fuel and its advantages. There are two broad classifications of burners (1) steam jet or air jet and (2) mechanical atomizing. Advantages and disadvantages of each are given. Shape and combination of openings in various burners appear to make little, if any, difference in burner efficiency. Data are included on htg. of oil, fur. vols. required, current prices of oil and a few typical burners are shown. R. D. L.

The analysis of fuel gas. S. W. PARR AND F. E. VANDEVEER. Univ. of Ill. Eng. Exp. Sta., *Circ.* **22,** No. 12, 8.—A 41 pg. bull. giving in convenient and concise form, practically all information necessary for analysis of the fuel gases, *i. e.*, by-product coke oven, retort, water and carbureted water and natural gases. A description of the Ill. Gas App., an adaptation of the Morehead type, which is a simple and accurate app. for gas anal., will be of interest to ceramic mfrs. R. D. L.

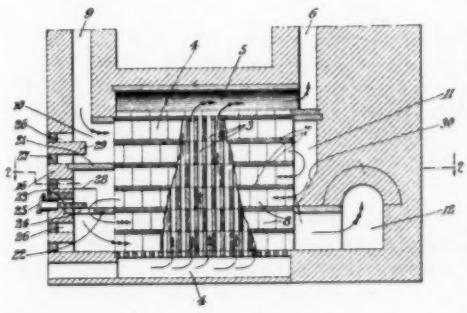
Oil burner has no atomizer. ANON. *Ceram. Indus.*, **4** [2], 156(1925).—A new mech. oil burning system is described. A feature of the burner is that it requires no atomizing agent such as steam or compressed air. P. D. H.

PATENTS

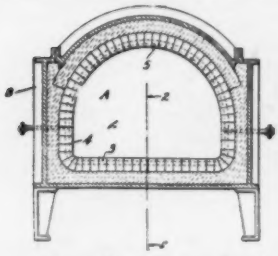
Tunnel furnace. CHARLES M. STEIN. U. S. 1,529,755, Mar. 17, 1925. The method of operating a tunnel furnace which comprises conducting a gaseous current, which is to enter into combustion, past the heated material to preheat the gaseous current, forming a combustible mixt. including said gaseous current, igniting the mixt., and passing the products of combustion along the material to be heated at a relatively higher velocity than that at which the gaseous current moves past the heated mat.



Recuperator structure. CHARLES M. STEIN. U. S. 1,529,756, Mar. 17, 1925. A recuperator structure comprising tiles having substantially vertical air passages therein, the tiles being built into parallel spaced columns, substantially horizontal plates extending between adjacent columns to provide waste gas conduits extending across the recuperator from side to side, chambers disposed respectively at said above-mentioned sides of the recuperator and in communication with said conduits, bracing members extending between the outer walls of said chambers and the outer sides of the end tiles of the several respective columns, and substantially horizontal baffle plates extending across one of said chambers and supported by said bracing members to divide said chamber into upper and lower sections, individual draft regulators being provided between adjacent pairs of bracing members in one of said chambers.



Electric furnace. HARRY A. MULVANY and HARRY E. KENNEDY. U. S. 1,529,368, Mar. 10, 1925. In a fur. of the character described, a brick lining, each brick of said lining consisting of a base portion, a head at each end thereof, a central web extending between the head members and forming a part of one of the head members, said web being separated and notched with relation to the opposite head member, said brick when placed in the furnace being alternately reversed, said webs when the brick are reversed forming zigzag channels between the brick, and a heating element of zigzag formation adapted to be placed in the channels and supported at opposite ends by the notched portion of each brick.



Oven for firing refractories and the like. HEINRICH KOPPERS. U. S. 1,528,555, Mar. 3, 1925. A ring fur. for firing ceram. ware and the like comprising a plurality of chambers, partitions sepg. said chambers, ports at the lower ends of said partitions communicably connecting the lower portions of adjacent chambers with each other, ducts communicating with each of said ports through which means may pass to shut off communication through said ports, other ports at the lower ends of said partitions, said ports communicably connecting with an upwardly extending channel, said last mentioned ports and channels communicably connecting the lower portion of one chamber with the upper portion of the next adjacent chamber, ducts leading to each of said last mentioned channels and ports through which means may pass to shut off communication through said ports.

Geology

Origin of red soils. E. BLANCK AND F. ALTEN. *Landw. Vers. Stat.*, **103,** 73–90 (1924); *Jour. Soc. Chem. Ind.*, **44B,** 20(1925).—The effect of humic colloids on the penetration of iron compds. into clays and soils is examined. By allowing solns. of iron salts to drop very slowly from capillary tubes on to powd. marble and dolomite it was found that in the absence of humus the iron is pptd. immediately on the surface of the particles, whereas in presence of humus it penetrated much further. Differences in color were observed. The bearing of these expts. on the origin of red clays is considered. H. H. S.

Fluorspar in S. Africa. ANON. *J. Soc. Chem. Ind.*, **44,** 239(1925).—Fluorspar averaging 99.5% CaF_2 with a max. of 0.3% SiO_2 is found in the dolomite formation near Ottoshoop, Zeerust. Owing to the extraordinary purity of the ore, no prepn. is necessary, and a considerable export trade has lately commenced. H. H. S.

Belgian Congo minerals. ANON. *J. Soc. Chem. Ind.*, **44,** 239–40(1925).—Tin oxide (cassiterite) extracted in 1923 was 720 T.; uranium exports were 478 T.; and cobalt minerals are found. H. H. S.

Barytes (Canada). H. S. SPENCE. Can. Inst. Min. and Met., *Bull.* **155** (1925).—Canada possesses important barytes resources, which are little used to meet her requirements. Domestic demand is sufficient to enable a small mill to operate profitably, provided proper attention is paid to methods of preparation. The growing consumption of lithopone in Canada which is made from barytes and zinc, suggests that the manuf. of this mat. to meet domestic demand is quite possible. No lithopone is made in Canada at present. O. P. R. O.

Clay (Saskatchewan). ANON. Sask. Bureau of Ind. (Regina), *4th Annual Report* (1924).—Among the known and tested deposits of Sask. clay may be listed those suitable

for use, wholly or in part, in the manufacture of: pottery or light ware, heavy ware, and refrac. These clays have been classified; records of tests are given from various districts; firing properties; fired color; chem. anal.; and a general brief resumé of clays of the Province in general are given. O. P. R. O.

Silica (Canada). L. H. COLE. Can. Inst. of Min. and Met., *Bull.* **155** (1925).—Silica; its production; producing and prospective producing localities; method of prepn. for market; disposition of products; and present market conditions are discussed. O. P. R. O.

Feldspar (Canada). H. S. SPENCE. Can. Inst. of Min. and Met., *Bull.* **551** (1925).—Feldspar; its deposits; producing and prospective producing areas; methods of preparation for market; disposition of products; and present market conditions are surveyed. O. P. R. O.

Graphite (Canada). H. S. SPENCE. Can. Inst. Min. and Met., *Bull.* **155** (1925).—Canada possesses important flake graphite resources, the ore-bodies being among the richest of those known and exploited on this continent. Cost of mining and recovery of the flake from hard gneissic ores puts operators at a serious disadvantage, and permits of cheaply-won Madagascar flake underselling the Canadian products in the U. S. market. There are no domestic crucible works to absorb production, and the Brit. and European markets are taking increasing amts. of Madagascar flake. O. P. R. O.

Alunite (New South Wales). L. F. HARPER. Geol. Surv., *Bull.* **8** (1924).—This bull. gives a brief record of alunite in New South Wales. Only one workable deposit has yet been found, and geol. investigations have been restricted as regards this occurrence. O. P. R. O.

Bauxite. L. F. HARPER. (New South Wales.) Geol. Surv., *Bull.* **8** (1924).—Aluminium (alunite and bauxite): Much more field and lab. work is necessary before detailed acct. can be given in regard to bauxite. Some of the analyses of trial samples indicate that true bauxite occurs in N. S. W., and attention is drawn in this bull. to possible value of the deposits from which these analyses were obtained. O. P. R. O.

Refractory clays of central Russia. M. M. PRIGOROVSKII. *Matter on natural resources of Russia*, No. **35,** 59 pp.(1922); *Rev. Géol.*, **5,** 98–9.—There are 5 types of deposits: (1) sandy clays with 50–60% pure clay, used for making saggers; (2) nearly pure clay with 85–92%, contg. fossil wood used for earthenware; (3) carbonaceous clay, 70–80%, with flakes of mica, particles of carbonaceous matter, and pyrite, used sometimes for saggers; (4) micaceous clay; (5) foliated clay. The purer clay is sedimentary; the others were formed by the alteration of limestones. (*C. A.*)

Bauxite associated with siderite. E. F. BURCHARD. *Bull. Geol. Soc. Am.*, **35,** 437–48(1924).—A new bauxite field has been found in N. E. Mississippi. Associated with the bauxite are lenticular masses of siderite, 6 to 20 in. thick, which alter easily to limonite. Most of this bauxite contains so much Fe_2O_3 and SiO_2 that it is considered low to medium grade: Al_2O_3 (bulk) 35–45%; Fe_2O_3 5–35%; SiO_2 10–30%. Geologic relations seem to indicate a deposition in fresh water peat swamps. (*C. A.*)

Chemistry and Physics

The effect of prolonged grinding on the density of quartz. A. J. DALE. *Trans. Ceram. Soc.* (Eng.), **23,** 211–6(1924).—The density of a given sample of quartz is dependent on the grain size of the sample taken, diminution of grain size, down to a certain limit, causing a slight increase in the d. of the mat. Prolonged grinding of vein quartz in an agate mortar causes a reduction in d. H. F. S.

Mechanical composition curves of soils, clays, and other granular substances. G. W. ROBINSON. *Jour. Agri. Sci.*, **14,** 626–33(1924); *Jour. Soc. Chem. Ind.*, **44B,** 19(1925).—A study of the mech. compn. curves of typical soils, clays, etc. With mats.

of uniform origin, such curves are smooth and, for ordinary soils, of a sigmoid type. The steepest portion of the curve gives the modal fraction, *i. e.*, the fraction present in greatest frequency. In very heavy clays the modal fraction is at the lower limit of the range, while for mechanically disintegrated mats. it is at the upper limit of the range of particle size. The use of the logarithm of settling velocity in water is recommended as a measure of particle size. For ordinary clays and soils the lower limit appears to be given by $\log v = \bar{7}.0000$. The limit for "clay" in mech. anal. should, it is suggested, be $\log v = \bar{5}.0000$. H. H. S.

Base exchange in relation to adsorption. E. A. FISHER. (Faraday Soc. Meeting, Dec. 2, 1924.) *Jour. Soc. Chem. Ind.*, **44**, 114(1925).—Many of the so-called adsorptive processes that go on in soils can be explained equally well on the basis of classical chemistry. The dyeing of wool shows many points of resemblance to absorption by soil, and the two sets of phenomena are too similar for them to be entirely unrelated. True adsorption probably plays an insignificant rôle in the soil; and with many other colloidal mats. also "adsorptions in colloidal systems" is synonymous with "the chem. reactions of colloidal subs." H. H. S.

Volumetric determination of Pb_3O_4 in red lead. E. F. FIGG. *Jour. Soc. Chem. Ind.*, **44**, 68T(1925).—M. LIEBIG's method of treating red lead with acetic acid and a known amt. of sodium thiosulphate, and titrating back with iodine, suffers from the fact that a copious ppt. of PbI_2 masks the end-point. L. uses a large excess of sodium acetate to prevent the pptn. This method gave 88.0% Pb_3O_4 as against 86.8% by the method of DIEHL and TOPF, and the higher figure is regarded as more accurate. H. H. S.

Adsorption. A. V. SLATER. *Jour. Soc. Chem. Ind.*, **44**, 161–4(1925).—Absorption is the process in which mols. of two subs. completely intermingle to form homogeneous mixtures or solns.; adsorption is the concentration of one subs. at the surface separating it from another, causing a layer of increased concn. only a few mols. thick at most. Adsorption follows Freundlich's formula $V = KC^{1/n}$ where V is the amt. adsorbed, C the concn. in the liquid and K and n constants depending on the nature of the soln. and the adsorbent. Defining a polar subs. as one affected by an electric field, and a non-polar subs. as one not thus affected, the rule is that polar adsorbents adsorb polar subs. and non-polar adsorbents adsorb non-polar subs. from soln. better than adsorbents from the other class in each case. Thus silica gel adsorbs polar subs. like water most easily, while active carbon has a greater attraction for non-polar subs. such as benzene. The effect of chem. attraction on adsorption is given by Langmuir's formula:

$$M = \frac{No}{N} \cdot \frac{y^{\mu}}{1 + y^{\mu}}$$

where M = mols. adsorbed; No = number of available valencies per unit area; N = Avagadro constant 6.1×10^{23}; y = rate of evaporation from completely covered surface; μ = number of atoms or mols. striking the surface. H. H. S.

X-ray laws in the field of optics. R. A. MILLIKAN AND I. S. BOWEN. *Proc. Nat. Acad. Sci.*, **11**, 119–22(1925).—It is proved exptly. that Moseley's law, with its corollary, the irregular-doublet law, holds in the field of optics as in the field of X-rays. H. H. S.

Conversion of flint into amorphous quartz. RICHARD GRÜN. *Stahl u. Eisen*, **44** [30], 883–7(1924).—Testings of the author about the conversion of the cryptocrystalline flint into amorphous quartz showed that in heating the flint over 1200°C a noticeable conversion takes place. The d. decreases with increasing temp. At 1500°C the d. of tridymite is reached. As the conversion takes place very fast, and the

flint becomes constant in vol. after being fired once, it possible to use flint in manufacturing refrac. W. S.

Influence of alumina and magnesia on the chemical properties of silicate slags. Bo KALLING. *Jernkontorets Annaler*, **108,** 283–307(1924).—The examns. were based upon the principle of detg. the state of equil. in the liquid phase between the slag to be examd. and a metal bath of known compn. As metal baths, 18 alloys with increasing Si content, from 0.64 to 10.15% of Si, were used. The other constituents were 80–73% Mn, 6.35–3.3% C and 12.8–13.2% Fe. The slag was fused in an elec. resistance furnace in a crucible of Acheson graphite. When the charge was melted and the temp. had reached 1600° the metal was added in a pulverulent state, 15 g. in each expt. This small quantity was used in order that a variation in the compn. of the metal bath should have the least possible influence upon the compn. of the slag. After addn. of the metal the crucible with contents was kept at const. temp. for 1 hr. or more and then cooled, and the Si content of the metal was detd. If it had decreased an alloy with less Si was used in the next expt. This procedure was repeated until an increase in the Si content of the metal could be observed and so the point of equil. could be fixed rather exactly. The various slags were prepd. with the least possible content of FeO in order to obtain a sort of equil. between FeO in the slag and Fe in the metal. It appeared that the Fe content in the metal increased a little during the expts., but not more than 0.2–0.6%. Special care was taken that the furnace gases should not react with the slag. The first slag examd. contained SiO_2 46, MnO 10, FeO 0.25, Al_2O_3 1.0, MgO 0.6 and CaO 42.2%. Equil. was found with a metal contg. 8% Si. When the Al_2O_3 content was increased this compd. acted as an alkali, moving the point of equil. to a metal with less Si. In this slag 1 Al_2O_3 corresponds to 0.14 CaO, or 1 Al_2O_3 = 0.23 CaO when calcd. by wt. The effect of MgO was like that of CaO when calcd. by wt., or in equiv. 1 MgO = 0.72 CaO. Similar expts. were then carried out with a more basic slag contg. SiO_2 37, MnO 6.5, FeO 0.4, Al_2O_3 6.7, MgO 0.7 and CaO 48.8%. Equil. was found with a metal contg. 1.50% Si. In this slag Al_2O_3 acted as an acid and to just the same extent as its basic action in the more acid slag, 1 g. of Al_2O_3 neutralizing 0.23 g. of CaO, or 1 Al_2O_3 = 0.14 CaO by equivalents. MgO was nearly equiv. to CaO by wt., or in equivalents 1 MgO = 0.69 CaO. In regard to their influence upon S and P in metal baths, MgO and CaO can be considered equiv. when calcd. by wt.; Al_2O_3 has only very little influence. (*C. A.*)

Density of the oxides of zirconium and hafnium. G. HEVESY AND V. BERGLUND. *J. Chem. Soc.*, **125,** 2372–5(1924).—The oxides were prepd. from the sulphates by driving off excess of H_2SO_4 at 400° and igniting finally at 1000°. The ds. at 20° are for ZrO_2 5.73, and for HfO_2 9.67. The oxides prepd. from basic sulphates or from oxychlorides give values lower by as much as 0.2. The Hf content of Zr samples may be found with a fair degree of accuracy from the d. of the oxide prepd. from the normal sulphate. (*C. A.*)

The separation of small quantities of calcium from large quantities of magnesium. V. RODT AND E. KINDSCHER. *Chem.-Ztg.*, **48,** 953–4, 964–5(1924).—The results of a series of expts. show that it is practically impossible to accomplish a successful sepn. of Ca from Mg by the conventional oxalate method when the Ca content amts. to only a few mg. in the presence of Mg equiv. to 1 g. MgO. On the other hand, more satisfactory results can be obtained by depending upon the soly. of $MgSO_4$ in dil. alc. in which $CaSO_4$ is practically insol. To the soln. contg. a little Ca and considerable Mg as chlorides, add sufficient *N* H_2SO_4 to effect the decompn. of the Ca to $CaSO_4$ and evap. to dryness in a porcelain dish. Take up the residue in 3 cc. of water and heat on the water bath until the soln. becomes very thick on cooling. Then, while stirring well, add a mixt. of 10 vols. EtOH and 90 vols. MeOH until the vol. of liquid amts. to 50 cc. After

a short time filter and wash the residue well with a mixt. of 5 vols. EtOH and 90 vols. MeOH. Ignite the residue of nearly pure $CaSO_4$ and dissolve the ash in dil. HCl. Add $(NH_4)_2C_2O_4$ to ppt. CaC_2O_4 in the usual way and det. the oxalate content of the ppt. by $KMnO_4$ titration. The results should be accurate within a few tenths of a mg. (*C. A.*)

The separation of cadmium and zinc by means of hydrogen sulfide. G. LUFF. *Z. anal. Chem.*, **65**, 97–109(1924).—Although the soly. products of CdS and ZnS lie closely together, it is possible to effect a quant. sepn. of 0.2 g. of Cd, or less, from as much as 0.2 g. of Zn, provided care is taken to maintain conditions favorable to the deposition of cryst. CdS. Six methods out of 12 tested gave excellent results. Thus a quant. pptn. of CdS was obtained in the cold in a soln. contg. 9 cc. of concd. H_2SO_4 and 20 g. of $(NH_4)_2SO_4$, by introducing H_2S for 15 mins. and then gradually diluting to 135 cc. If the pptn. is started at near the b. p., the H_2S should be passed for 15 min., then small portions of water added at 5-min. intervals until in about 30 min. the vol. of soln. is increased to 135 cc. and finally the soln. is allowed to cool while H_2S is still passed. A similar procedure with not more than 11 cc. of concd. HCl also gave good results. (*C. A.*)

Electrolytic separation of copper, antimony, lead and tin. A. LASSIEUR. *Compt. rend.*, **179**, 827–9(1924).—A method of analysis has been worked out, and will be published elsewhere in detail, which permits the successive electrolytic detn. of Cu, Sb, Pb and Sn. The Pb-Sn sepn. takes place in 225 cc. of soln. contg. 20 cc. of concd. HCl, 5 cc. of concd. HF and 1 g. of $NH_2OH.HCl$ with a carefully regulated cathode potential. The electrolysis of the Pb is started at 60° and this temp. is maintained for 10 mins. after which the electrolyte is cooled to 20°. The Pb is deposited quant. as metal and no Sn is deposited if less than 0.375 g. of Sn is present. It is necessary to have the Sn in the highest state of oxidation, so that after the detn. of Sb, the soln. should be oxidized with H_2O_2. After the removal of the Pb, the soln. can be treated with 10 g. H_3BO_3 and 10 g. of $(NH_4)_2C_2O_4$, dild. to 300 cc. and electrolyzed for Sn with a Cu-covered cathode. (*C. A.*)

The detection of lead in kitchen pottery. C. DEBRUN. *Ann. fals.*, **17**, 467(1924).—The following procedure is recommended as being more sensitive for detecting small traces: Pour 100 cc. of 6% AcOH in the container to be examd., cover with a glass plate, let stand 24 hrs., wash the soln. into a porcelain evapg. dish, add 5–6 drops of 36° Bé. HNO_3, evap. to dryness on the water bath, take up in 5 cc. of boiling water, evap. to dryness, dissolve in 15 cc. boiling water, filter through a plain filter and wash to a total vol. of 50 cc. To 10 cc. of the filtrate add 5 drops of 10% KI (sensitive to 1 part in 30,000) or of 10% K_2CrO_4 (sensitive to 1 part in 100,000). When the amt. of Pb is near the limit of sensitiveness of the test, the $PbCrO_4$ begins to show up only about 15 min. after adding the precipitant and pptn. is complete only after 2 hrs. (*C. A.*)

PATENTS

Process of making arsenate of lead. HENRY HOWARD. U. S. 1,529,998, Mar. 17, 1925. Process of making arsenate of lead which comprises heating to reacting temp. a mixt. containing arsenious oxid, a higher oxid of lead, a catalyst, and water in quantity at least sufficient to form a stiff paste.

Method of separating impurities from solutions of tin salts. SIMON JOSEPH LUBOWSKY. U. S. 1,529,260, Mar. 10, 1925. The method of sepg. solid mat. in suspension from solns. of tin salts which comprises forming a hydrated oxide of tin in the soln. of tin salts to carry down the suspended matter, and then withdrawing the supernatant liquid.

Method of producing crystalline oxide of tin. SIMON J. LUBOWSKY. U. S. 1,529,261,

Mar. 10, 1925. The method of producing a colored crystalline oxide of tin from pptd. tin hydroxides, which comprises heating the initial product at a temp. above 1900°F, for a period of time sufficient to produce the desired color value, and suspending the heat treatment, when the desired color value is shown.

Process for manufacturing aluminum compounds. EDSON R. WOLCOTT. U. S. 1,528,039, Mar. 3, 1925. The process which consists in subjecting a mixt. of aluminum silicate mat. and carbonaceous mat. to heat to effect destructive distillation of the carbonaceous mat., collecting the products so distilled, subjecting the residual mixt. of aluminum silicate mat. and residual carbon to further heating action in the presence of a halidizing agent to produce and volatilize a halide compd. of aluminum, separating such compd. from the gases and vapors passing off therewith in the volatilization operation, and treating the residual gases with material capable of absorbing the halogen in such gases and vapors to form a halide and returning the halide so formed to the htg. and volatilization stage of the cycle of operations.

Zirconium compounds and pigments. D. TYRER. Brit. 217,323, March 14, 1923. White pigments contg. ZrO_2 and alk. earth sulfate are obtained by pptg. together ZrO_2 or basic Zr sulfate and an alk. earth sulfate and calcining the pptd. mixt. Several detailed procedures are described for obtaining Zr compds. from ores and making pigments of this character. *E. g.*, Zr ore may be treated with H_2SO_4 to effect partial extn., the solidified mass dissolved in H_2O and the residue of the ore, alone or mixed with fresh ore, heated with $BaCO_3$ or a mixt. of $BaSO_4$ and C and flux and the product contg. zirconate dissolved in HCl. The solns. of chloride and sulfate may then be mixed in such proportions that the whole of the sulfate radical is pptd. by the alk. earth chloride present. $BaCO_3$ is then added to ppt. the remainder of the Zr and the entire ppt. is then sepd., dried and calcined, preferably at 1000°. (*C. A.*)

Alumina and aluminium chloride. HÖGANÄS-BILLESHOLMS AKTIEBOLAG. Brit. 217,568, June 15, 1923. In the manuf. of Al_2O_3 by treating clay, argillaceous slate or bauxite with HCl, pptg. $AlCl_3$ by HCl gas and calcining the chloride, the mixt. of HCl and steam liberated in calcining the crystals is used for pptn. of chloride from the soln. and part or all the mother liquor after sepn. of the crystals is used for dissolving more raw material. (*C. A.*)

General

Terra sigillata not Samian ware. J. W. MELLOR. *Trans. Ceram. Soc.* (Eng.), **23,** 176–7(1924).—Terra sigillata was edible clay mined on the islands of Samos and Lemnos. It was used for many centuries, from at least 300 B. C. until the close of the Middle Ages, as a medicine. The red Samian pottery of the Romans had no connection with or relation to terra sigillata. H. F. S.

Note on the use of woodwool as a packing material. B. OLSEN. *Trans. Ceram. Soc.* (Eng.), **23,** 182–4(1924).—Restrictions affecting the use of straw for packing for fear of its acting as a carrier of the foot and mouth disease has led to the considerable use of woodwool for packing in Europe. Woodwool costs more than straw, but it cuts down breakage in transit, and is clean and dustless in use. When freshly made it is soft and pliant. H. F. S.

Sedimentation as a means of purifying clay. S. R. HIND. *Trans. Ceram. Soc.* (Eng.), **23,** 234–52(1924).—Sedimentation (as a consequence of deflocculation) notably reduces the percentage of iron in the clay, but does not eliminate it entirely. The osmosis machine effects no further sepn. of iron. Sedimentation either does not affect the propn. of other impurities (titania alkalis and alkaline earths) or slightly concentrates them with the clay. The osmosis machine does not affect these impurities. Sedimentation gives a finer grained product and increases the contraction on drying

and firing and increases the refractoriness of the clay. The osmosis mach. produces practically no further effect on these properties. Treatment with silicate of soda, by the deposition of gelatinous silicic acid on the clay, causes it to be workable with a higher propn. of water, and the dried clay shows a higher porosity. H. F. S.

Coal as an industrial fuel. D. J. DEMOREST. *Chem. Met. Eng.*, **32**, 274–6 (1925).—The factors detg. the choice of coal for various heating operns. are discussed For steam raising, with a given price for coal, the coal to buy is the one with the greatest number of B. t. u. per lb., the highest ash fusion point, and which gives the least amount of trouble from coking or smoking. The best producer coal is a high volatile, low sulphur, low ash, high ash fusion temp., high B. t. u., coal which does not coke badly. It should be sized. The requirements for coking coals are good coking properties, low ash and low sulphur. Discussing powdered coal, the author cites two plants whose costs of powdering are respectively $0.60 and $0.70 per ton, on a production of 500 and 1000 tons. The greatest difficulty in the use of powdered coal is the ash problem. Its use in power plants is of doubtful efficiency, but for cement kiln heating it is ideal. M. E. M.

Cost of atomizing fuel. CHAPLIN TYLER. *Chem. Met. Eng.*, **32**, 323(1925).—Figures are given showing equipment cost, fixed charges and maintenance, cost of steam, and cost of air, for fuel oil installations of various sizes. M. E. M.

Definition of the expression "Ceramics." Report of the international chemical union. *Chimie et Ind.*, **1924**, special number, 411–4. W. S.

Natural gas in Canada and its uses. R. T. ELWORTHY. Can. Inst. of Min. and Met., *Bull.* **155**, 1925.—Natural gas is found in commercial quantities in 3 provinces in Canada, New Brunswick, Ontario, and Alberta. E. discusses the uses of natural gas; the compn. of Can. natural gas; natural-gas gasoline; carbon black; helium; and the indus. chem. produced from natural gas. Natural gas, for which there is no domestic demand at present, has possibilities of becoming the basis of important industrial developments, if constant attention be given to the research problems involved. O. P. R. O.

Steam generation under critical conditions. (Benson process.) D. BROWNLIE. *J. Soc. Chem. Ind.*, **44**, 213–9(1925).—Progress in the technique of steam generation has been greater in the past ten years than in all the previous period. The conversion of water on a practical scale into dry satd. steam under the critical conditions of 3200 lb. per sq. in. press. at 706°F (375°C) enables 30–35% thermal efficiency to be obtained from the raw coal to the switchboard. The MARK BENSON process generates steam at high press. in a narrow bore coil in such a manner that the troubles caused by ebullition are entirely avoided. The plant, as erected at Rugby, Eng., consists essentially of a very long coil of steel tubing $^1/_4$″ thick and $^3/_4$″ bore, arranged vertically between an inner and outer casing of refrac. mat. The coils are 8 ft. high and form the actual generator. On the top of them are subsidiary coils for super-htg. and the whole arrangement, approx. 17 ft. high and 7 ft. in diam., is htd. from the top by an oil blast while distilled water is passed in continuously at the bottom at 3200 lbs. press. The water traveling upwards reaches 706°F within 10% of the discharge end, and in the remaining 10% of the coil is slightly superhtd. at about 720°F, the press. all the time being 3200 lbs. Ebullition is thus eliminated. H. H. S.

Cobalt: its production and uses. T. H. GANT. *Jour. Soc. Chem. Ind.*, **44**, 157–61(1925).—Cobalt occurs in the following forms, of which smalite, cobaltite, and asbolite are the most important: coballite or cobalt glance, CoS_2, $CoAs_2$; smaltite, $CoAs_3$; linnalite or cobalt pyrites, CoS, Co_2S_3; crythrite or cobalt bloom, $Co_3As_2O_8$, $8H_2O$; willyamite, CoS_2, NiS_2, $CoSb_2$, $NiSb_2$; skutterudite, $CoAs_3$; asbolite, an impure mixt. of Mn and other metallic oxides contg. up to 30% CaO; spacerocobaltite, $CaCo_3$,

and its hydrate remingtonite; safflorite, $CoAs_2$; glancodot (CoFe), AsS. The chief sources of supply are Cloncurry, Queensland, and Nipissing, Ont. Speiss from Nipissing residues contains 17.55% Co, 18.82% Ni, 12.04% Fe, 8.15% Cu, 0.91% Ag, 6.69% S, 35.14% As, Speiss from Australian ores contains 43.14% Co, 1.0 Ni, 10.0 Fe, 30.03% As, 15.04% S. As prepd. for commerce, cobalt "black oxide" contains 70% Co, "special oxide" 72% Co, and "prepared oxide" 75% Co. Nickel hydrate is recovered as a by-product, roasted, and graded as: "OG" contg. 68–70% Ni; "G" 73% Ni; DR 73–76% Ni. The "black oxide" of Ni contains 76–77% Ni. Ferro-cobalt is marketed in cubes contg. 10–15% Fe and 80–90% Co for use in the iron and steel industry. Thénard's Blue is $CaO.Al_2O_3$; Rinnan's green, CaO.ZnO mixed with ZnO. Margarine blue is obtained by calcining 68 parts CaO, 16 Cornish stone, 12 flint, 4 whiting. $BaCO_3$ may be substituted for $CaCO_3$, and ground pitchers introduced as well. Colors are more resistant to the action of the glaze if built up on the spinal type $RO.R_2O_3$; *e. g.*, $(4CaO.6ZnO)Al_2O_3$. The defect of "ironing" may be remedied by adding Al_2O_3 or TiO_2. "Flows blue" is obtained by putting white lead and salt in the saggers with the cobalt glazes. In pottery bodies, CaO acts as a whitener in the proportion of 1:2240 parts of dry body. It is best first ground with 10% china clay. H. H. S.

Formation of Italian Ceramic Society. *Jour. Soc. Chem. Ind.*, **44,** 35(1925).—At the first congress of Italian ceramists, held in Turin, it was decided to establish a national ceramic society with headquarters at Pesaro. H. H. S.

Artificial ruby and sapphire. F. WINTELER. *Tech. ind. schweiz. chem.-Ztg.*, No. **17/18,** 180–3(1924).—Artificial ruby, made by melting Al_2O_3 to which mineral coloring m. tter has been added, consists of a mass of microscopic crystals having different optical properties from the mineral. It is employed principally in the watchmaking industry. Natural rubies and sapphires from different localities vary in hardness and in sp. gr., the latter ranging from 4.0 to 4.3, the sp. gr. of the artificial ruby being 3.95. Analysis shows the minerals to contain besides Al_2O_3, Mg, Zr, Ti, Be and Si. The Mg content of oriental ruby may reach 15%, and is presumably present as Mg aluminate. The other elements are believed to be present as salts. In the synthetic ruby Cr gives red, Co and V blue, Ti yellow, Ti + V green, Au brilliant red.

Heat losses from steam-line pipes. R. H. HEILMAN. *Blast Fur. Steel Plant*, **10,** 261–5(1922).—Data are given on bare pipes operating at temps. up to 427 together with curves and formulas, enabling ready solution of problems encountered in the calcn. of heat losses from bare and covered pipes. The general formula giving good results is $T_d = 272.5\ h/[h + (564/D^{0.19})]$. T_d = temp. difference between canvas surface and room (°F); h = total B. t. u. loss per hr. per sq. ft. of canvas; and D = outer surface diam. (inches). An example is given. (*C. A.*)

Calculating the useful height of cupolas. M. M. KARNAOUKHOV. *Messager tech.-écon. russe*, **1923,** 340–3; *Rev. métal.*, **21** (Extraits), 453–4(1924).—The "useful height" is the height from the axis of the tuyères to the bottom of the charging hopper, and is given with a sufficient degree of approximation by the formula: $H = [0.270D - \sqrt{0.0729D^2 - (49D^2/R)}]/0.0245$, in which H = useful height in m., D the diam. of the cupola in m., R the wt. of the charge in kg. The formula is deduced from Hueser's heat balance (*C. A.*, **7,** 1692) and holds for similar conditions. A more general formula is: $H = [(1 - K_1 - C)D \pm \sqrt{(1 - K_1 - C)^2D^2 - (4K_3K_2D^2/R)}]/2K_3$, in which K_1 = chem. heat of the gases discharged/calorific value of coke, $K_2 = \beta_1HR/AD$ = [phys. heat of gases discharged × height × R]/(calorific value of coke × diameter), K_3 = (loss by radiation × diameter)/(calorific value × useful height). K. is trying to det. the values of K_1, K_2 and K_3 for other cases found in practice. (*C. A.*)

Some moisture relations of colloids. II. Further observations on the evaporation of water from clay and wool. E. A. FISHER. *Proc. Roy. Soc.* (London), **103A,** 664–75

(1923); cf. *C. A.*, **17**, 2466, 2528.—The study of the evapn. of H_2O from colloidal materials has been extended to kaolin and a ball clay. When the rate of evapn. is plotted against moisture content, the curve for ball clay does not show the curvature previously noted in a clay subsoil and attributed to shrinkage, although the ball clay also shrinks. This type of curvature is found only with materials which are mixts. of colloidal and non-colloidal substances, and is due to the simultaneous evapn. of imbibitional H_2O held by the colloid and of interstitial H_2O held as H_2O wedges between the soil grains. The former H_2O evaps. at a practically const. rate, while the latter evaps. at a rapidly diminishing rate. The bearing of these results on the evapn. of H_2O from wool fabrics is discussed. (*C. A.*)

An attempt to cheapen the production of zirconium dioxide. J. W. BAIN AND G. E. GOLLOP. *Can. Chem. Met.*, **7**, 35–8(1923).—Brazilian zirkite runs 70 to 80% ZrO_2; only 55 to 65% of the Zr is actually present as ZrO_2; the remainder is silicate. In the Florida zirconia sands there is more Zr silicate and hence these sands are harder to treat. By passing dry Cl_2 or $COCl_2$ over heated Zr-bearing ore mixed with C, $ZrCl_4$ can be volatilized and pure ZrO_2 can be prepd. therefrom. The reaction is slow; the yields for Cl_2 are far from theoretical; and the process is difficult to carry out commercially. Fusions with (*a*) NaOH, (*b*) Na_2CO_3, (*c*) niter cake and (*d*) KHF_2 are described in *C. A.* **15**, 3952. Of the soln. methods the best employs 66° Bé. H_2SO_4. By using 2 pts. H_2SO_4 to 1 pt. ore and heating to approx. 275° for 1 hr., 1–7% of the ZrO_2 in some Brazilian ore is brought to soln. Higher temps. and longer time did not increase the yield. The usual methods of producing a pure ZrO_2 from the H_2SO_4 soln. are too expensive for com. work. After extg. the residue with hot H_2O, the ZrO_2 can be pptd. by boiling as basic sulphate (Pugh's pat. U. S. 1,316,107). To reduce the free H_2SO_4 to approx. half that of the ZrO_2 present, addn. of (1) $CaCO_3$, (2) $CaCl_2$ and (3) $CaCO_3 + CaCl_2$ were tried. B.'s and G.'s expts. show that Zr is retained by the pptd. $CaSO_4$, and that great diln. is necessary to bring down the ZrO_2 in appreciable amt. by boiling. By suitably adjusting the concns. and dilg. the filtrate about 40 times before boiling, about 75% of the ZrO_2 in soln. can be pptd. The ppt. merely requires washing and ignition. One sample so obtained gave on analysis 98.6% ZrO_2. (*C. A.*)

Edward Goodrich Acheson. F. A. J. FITZGERALD. *Ind. Eng. Chem.*, **16**, 971 (1924).—Biography, with a portrait. E. H. (*C. A.*)

PATENTS

Porous concrete aggregate. BERNARD J. FALLON. U. S. 1,528,759, Mar. 10, 1925. The process of forming a clay product which consists in first firing a mass of clay in a kiln under oxidizing conditions, then in passing steam through the bed of burning fuel into the presence of the clay and continuing the firing of the clay in the atmosphere so produced.

Process of forming ceramic products. ALBERT V. BLEININGER. U. S. 1,528,908, Mar. 10, 1925. The process of forming ceramic products which consists in prepg. a ceram. mass contg. deflocculated clay mat., adding thereto a coagulating reagent to effect delayed chem. reaction, and placing the mixt. in a mold.

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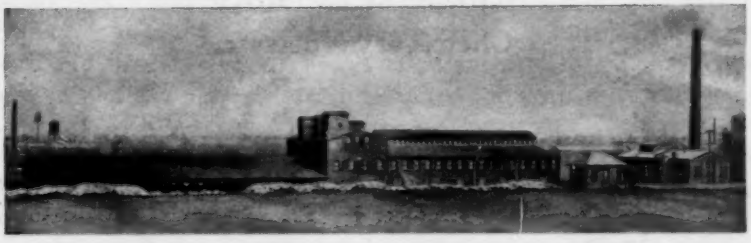

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BULLETIN

of the

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A Monthly Publication Devoted to Proceedings
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of Technical, Scientific and Art Questions and
Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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Vol. 4 May, 1925 No. 5

EDITORIALS

CERAMIC RESEARCH INSTITUTES

Two research institutes have been launched. The Clay Products Institute and the American Refractories Institute have organized and started coöperative research work. They represent collective efforts of plant owners to secure from research and education what individuals working alone can obtain only at large money and time expenditure. Coöperation and coördination are requisite to completeness, thoroughness and speed in developing information essential to keeping apace with the ever-pressing economic and quality demands. This has been the motive of those who have labored through the American Ceramic Society. This Society would be unfaithful if it did not give every encouragement to whatever organization scheme the ceramic manufacturers may wish to set up to obtain the most efficient coöperation. This Society lauds the principles and the purposes which actuated the men who are responsible for the formation of these two Research Institutes.

For several years this Society has urged coöperation by the financial interests in ceramics. These Institutes are justly viewed as resultants of the constant efforts which have been made to interest plant owners in research and education. This Society enjoys considerable satisfaction in the steadily growing support of coöperative research by the trade press and by the trade associations.

The remaining tasks for the AMERICAN CERAMIC SOCIETY are (1) to urge all groups of ceramic manufacturers to organize similar institutes or to show how they may join those already under way; (2) to assist in finding a flexible and economical means of coördinating the "over head" or general research activities in which all groups of ceramic manufacturers are mutually interested; (3) to continue an organization in which all ceramic technologists and scientists may have a clearing for and a means of recording results of research.

The AMERICAN CERAMIC SOCIETY belongs to ceramic people as generally as a republic does to its citizens. It is for and by all ceramic groups. Its scheme of decentralization of control and activities through the seven Industrial Divisions is not greatly unlike the decentralization in government by states. The steady growth in strength and in effectiveness of this *seven societies in one* and the continued harmony of the *seven simultaneous meetings* bespeaks unity in ideals and purposes of ceramic technologists generally, irrespective of the wares they produce. The SOCIETY truly is by, and for, all ceramists with special benefits to none not enjoyed by all.

This SOCIETY has operated for twenty-seven years in the manner dictated by its members. It has served important purposes which purposes have gradually increased in importance. So successfully has the SOCIETY promoted activities for the advancement of ceramic science, technology and art that not only has the SOCIETY grown in membership but ceramic schools have multiplied, the ceramic trade journals have increased in numbers and plant owners generally have come to a realization of the financial benefits of ceramic research and education. The character of subject matter in the trade press has changed from trade altogether until now a fairly large amount of space is devoted to presentation of strictly technical and scientific information and data.

The AMERICAN CERAMIC SOCIETY has done nothing and merits nothing not creditable to its individual members. The credit for the scientific and technical advancements in ceramics and the increased appreciation generally of the benefits of research and education belong to the individuals and to the manufacturing concerns. The SOCIETY itself is inanimate, it merely reflects the desire there has been for coördination of individual efforts to gain the largest possible ceramic knowledge at the least cost in time, effort and money. It has changed its procedures and activities from time to time to meet the changes in conditions and requirements resulting from the continually increasing employment of ceramic science. There is nothing more certain than that this SOCIETY will adjust itself to meet the new situation caused by the organization of research institutes by the plant owners because all that the SOCIETY now is and all that in the future it will be is in response to the needs of its individual members.

If in the extreme, this SOCIETY should be found impotent it will automatically cease to exist and that too with no regrets resident in the minds and hearts of anyone, not even of those who have labored most faithfully and continuously for the SOCIETY. It has been ideals and purposes for which supporters of the SOCIETY have worked rather than for a certain form of organization. If the several research institutes can find a means for joint collaboration in researches and a means of collecting and making information available they will then be serving the purposes for which this SOCIETY was organized and has been continued.

It is to this end that we have urged participation in and control of the affairs of the SOCIETY by plant owners. It has always been very evident that the several activities in which the SOCIETY through its committees has engaged would have been much more effectively executed had the plant owners been more intimately interested and in control. The fact that the SOCIETY has grown in membership, strength and in effectiveness shows that its purposes, methods and organization are not far wrong.

There is no expectation of this SOCIETY becoming impotent. It will not serve its most useful purpose until the plant owners through their respective trade associations or research institutes find ways and means of coördinating through the SOCIETY. This, of course, will be possible only when a means is worked out for direct control of the affairs of the SOCIETY by the industrial research groups or institutes.

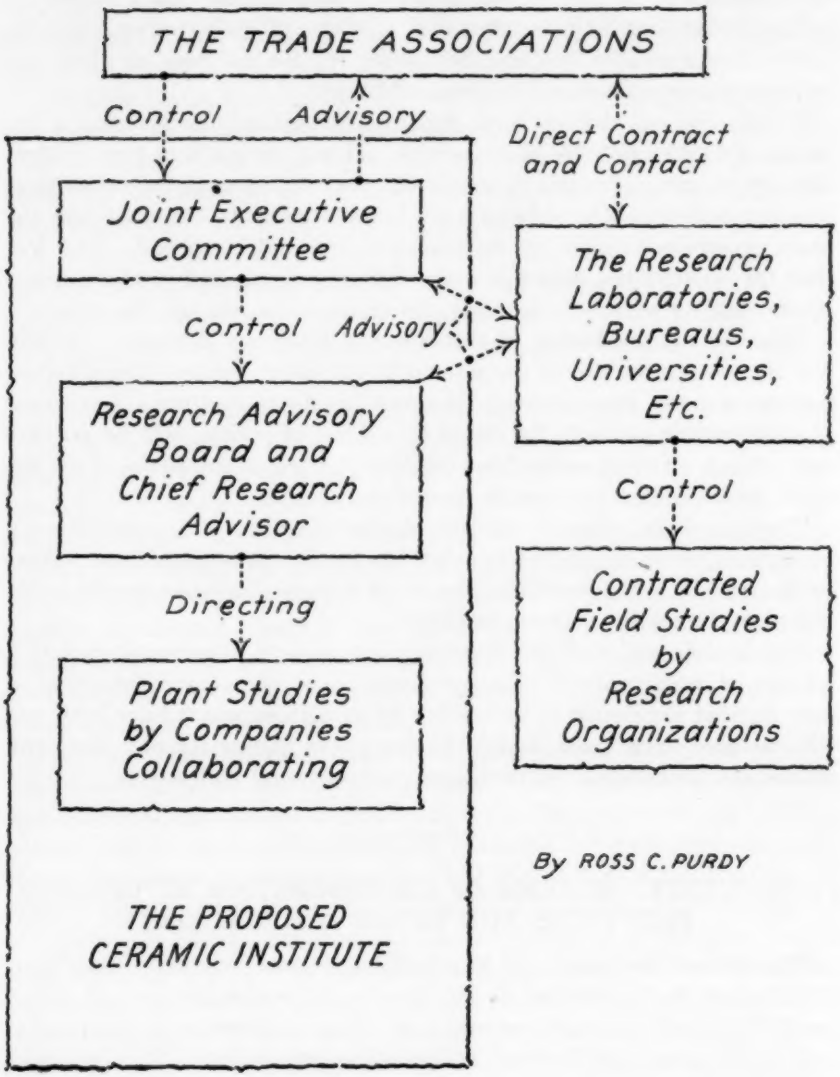
The smooth and effective working together for years of the self-governed Industrial Divisions of the SOCIETY shows the possibilities and points to the benefits which would accrue to all if these Divisions should be replaced by industrial research institutes.

It is to this end that the Secretary has made a recommendation of a scheme of collaboration. The presentation of the scheme proposed is only another suggestion to be considered with those which have been and will continue to be made, all for the purpose of finding the best ways and means of collaboration of ceramists generally and collectively.

A SUGGESTED SCHEME OF COLLABORATION BY CERAMIC INSTITUTES AND TRADE ASSOCIATIONS

The scheme here suggested is a national ceramic research council participated in and controlled by all ceramic industrial groups. It is not an arbitrary self-governed organization. It would operate in the manner and to the extent determined by ceramic plant owners. It is proposed that this council shall not conduct investigations but shall serve simply as a clearing-house for information and in an advisory capacity to the ceramic manufacturers' organizations and to the laboratories. It would

PROPOSED CERAMIC INSTITUTE RESEARCH ORGANIZATION



By ROSS C. PURDY

not be in charge of research nor have the right to contract for research. Its purpose would be to collect information and to advise on research problems and facilities.

Scientists observe, theorize and make record of the knowledge they originate. The latent values of scientific facts are translated into industrial aids only when plant technologists with a vision have the opportunity to assemble and apply them. Neither the laboratory worker nor the plant technologist alone can work out these things; they must collaborate closely. No research council can be effective that does not assure close collaboration of the plant technologist and the laboratory scientist. And the most searching and effective collaboration is had when all ceramists irrespective of the kind of ceramic ware produced and all the research laboratories have a common means for pooling their information.

The research institutions (bureaus and universities) are primarily laboratories and their investigations are limited to those which can be prosecuted in the laboratories. They can extend their observations to plant operations only in cursory fashion. Their research personnel cannot wholly acquire the knowledge, point of view and vision of the technical man whose daily work is factory routine and whose responsibilities primarily are product and production. Neither the laboratory nor the plant technologist has that complete information, vision, thought habit and interest which is necessary to the best selection, analysis and prosecution of an investigation of a plant problem. The laboratory scientist and the plant technologist so supplement one another that when joined in prosecution of a research they complete the requisite human ability to conduct researches most effectively. It is time industrial technologists be provided with a financed means of collaboration with men in the research laboratories and with their fellows in other lines of ceramic manufacturing. This provision is made in the scheme here presented. The Research Advisory Board would be composed of technical men from the plants, meeting frequently and doing assigned work at home.

A great deal of information most valuable to a given ceramic industry was originated by manufacturers of apparently wholly different types of ceramic ware. There is much which is basic in the fabrication of all ceramic wares, differing only in methods and means of applications. This is as truly the fact in the production of two quite widely different ceramic wares as it is true in the production of different varieties of the same class or type of ware. The manufacturer would gain effectiveness, breadth of vision and actual knowledge of facts in proportion to the varieties of experience and concepts of their research council. This council should be comprised of technologists from a wide variety of ceramic enterprises and should be in close relations with all of the research laboratories.

The organization chart here presented provides an effective means of

collaboration by plant executives, plant technologists and laboratory investigators. It provides for as little or as much collaboration of trade associations and research institutes as the research problem in hand would warrant. It provides for direct relation by each trade group separately or jointly with the research laboratories. The Research Advisory Board would not be a "go between" nor would it conduct laboratory investigations. Its work would consist of assembling facts and advising on research problems.

In this scheme, there is the maximum of flexibility, simplicity, economy and effectiveness. There is avoidance of duplication. It provides for complete supplementing of experiences, training and viewpoints of the business man, plant technologist and laboratory scientist of all ceramic trade groups. It gives the business owner that same exhaustive study and council on research problems and research facilities as they have in legal matters through their legal councillors. It furnishes the means of determining the abilities of universities to conduct researches. It provides council to both the manufacturer and the laboratory scientist in the conducting of ceramic investigations. The universities and bureaus are in need of this sort of industrial contact as are the manufacturers.

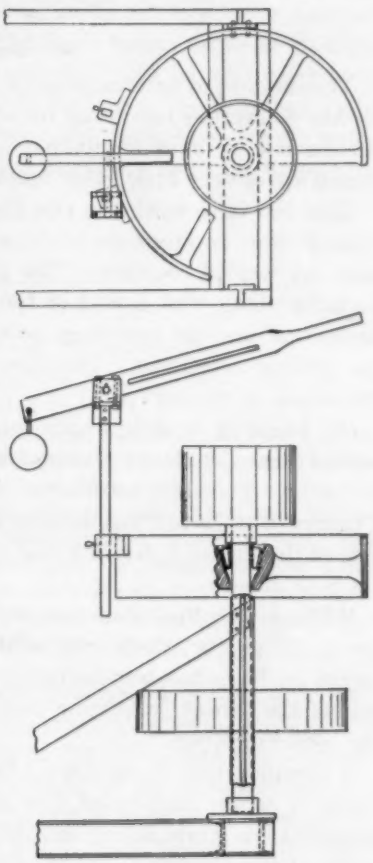
PAPERS AND DISCUSSIONS

A HOME MADE JOLLEY

By Wayne E. Barrett

Recently it was necessary to have a jolley for making some jiggered pieces from the clay used in the manufacture of a regular line of products. Since the task did not warrant the purchase of a machine, one was built.

The head was made by shrinking a six-inch iron band on a trued drier-car wheel from which the flange had been removed. This was then keyed to a shaft and trued up in a lathe.



A drive-wheel from an Elwell-Parker electric truck was used to support the shaft. The Timken taper bearing carried the weight of the head, shaft and drive pulley. This gave a smooth running wheel, entirely free from vibration. The lower end of the shaft was held in position by a babbitted foot bearing.

Two small T-irons carried the electric truck wheel while two pieces of drier-car slats were used to give a lateral bracing. This was all carried on a base consisting of two 4-inch channel irons 5 feet long and three 4-inch channels 18 inches long all fastened together by pieces of angle iron.

To support the pull-down, two worn-out brakes from a locomotive were bolted to the truck wheel. Each of these had a $^5/_8$ by $1^1/_2$-inch hole for the brake arm and this hole was taken advantage of by loosely fitting two uprights of $^5/_8$ by $1^1/_2$-inch strap iron by a set screw. This made possible a variable height for the tool or profile which shapes the pieces.

The top ends of these pieces of bar iron were slightly twisted to make them parallel and a small piece of cast iron carrying a small ball bearing was attached to each of them. These ball bearings carried a shaft to which was keyed the pull-down arm, made of $^3/_4$ x 3-inch bar iron. The

pull-down arm had been previously slotted by a portable lathe key-seating machine to allow for adjustments of the profile.

The wheel was driven by a quarter-twist belt over a motor pulley, and the motor controlled by means of a foot switch.

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A TEST FOR DETERMINING THE WELDING PROPERTIES OF GLASSES[1]

BY ROBERT J. MONTGOMERY

The method of determining the welding properties of glass as described by Mr. Sharp has been used for some time in our plant with considerable success but we have found that under certain conditions, the results obtained are of very little value unless certain factors are taken into account.

This test is to work the two glasses to be welded into rod form. The ends of these two rods are held together and heated to softness so that the ends are welded together. The junction is pulled out into a thread 10–15 inches long with a pair of forceps. The heavy end at the forceps is broken off and the curvature of the thread will indicate which glass has the greater expansion. The glass with the greater expansion will be on the inside of the curve.

We found in welding a soda-lime glass to a lead glass that if there was no curvature, indicating no strain, glasses would usually not weld satisfactorily. To give a satisfactory weld, a deflection of the thread of about 2 inches in 10 inches was necessary. This deflection was on the soda-lime side of the thread indicating that the soda-lime glass contracted more than the lead glass.

When a soda-lime glass was welded to a barium glass, the reverse was true. To give a satisfactory weld, a deflection of the thread of about 1.5 inches in 10 inches was necessary but this deflection was on the barium side of the thread, indicating that the barium glass contracted more than the soda-lime glass.

A consideration of the subject brought out that there were two different kinds of strain introduced into a drawn thread of this kind. First, of course, is the strain due to any difference in contraction due to the composition of the glass and second is the strain introduced by sudden chilling of the thread in air. The test piece is not annealed.

Annealing the test threads gave us the desired information. The lead-soda-lime combination straightened out and gave no curvature and the barium-soda-lime thread did the same. Apparently when the annealing

[1] A discussion of the paper by Donald E. Sharp, *Jour. Amer. Ceram. Soc.*, **4** [3], 219 (1921).

temperature of both glasses is the same or the composition of the two glasses is about the same, the strain introduced by no annealing is about the same in both. The strains then, being equal and opposite, caused no deflection. If the glasses are dissimilar in annealing temperature and composition, the thread will curve toward the one having the higher annealing temperature.

In annealing the threads, trouble was encountered unless they were held vertical so the thread would be affected only by the difference in expansion and not be bent at the annealing temperature by gravity. We have set the threads in plastic clay like an inverted Seger cone, and suspended this on a small iron stand which could be put into the leer. In some cases there is a tendency for the ends of the threads to curl up in the direction of the harder glass. In a lead-soda-lime fusion, the soda-lime glass would be on the inside of the curl. Evidently the annealing temperature was too high and the glass became quite soft.

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MEDIEVAL EUROPEAN POTTERY[1]

BY ROBERT F. SHERWOOD[2]

ABSTRACT

This paper deals with pottery and porcelain from the time of the Fall of Rome through the sixteenth century. Italian pottery before the Renaissance and Majolica ware are discussed under Italian pottery. French pottery is classed under the two heads of Faience and Palissy ware. The influence of the Moors and Arabs upon Spanish pottery and also the origin of Majolica ware is taken up under Spanish pottery. The pottery of England before the Norman period and after the Norman Conquest is discussed. The pottery of Central Europe is dealt with under the head of German pottery. Porcelain is discussed from 200 B.C. on through its introduction into Europe and up to the earliest imitations of porcelain in the sixteenth century.

The word "pottery" in its widest sense includes all objects fashioned from clay and then hardened by fire, though there is a growing tendency to restrict the word to the commoner articles of this great class and to apply the word "porcelain" to all finer articles. Chas. F. Binns makes the distinction between the "commoner articles of this great class" and porcelain; porcelain has a low biscuit fire and a high glaze fire, while the commoner articles have a high biscuit fire and a low glaze fire. For this reason porcelain will be discussed under a separate portion of this paper.

Time or space does not permit a discussion here of Greek and Roman pottery. Suffice it to say that the pottery of the Greeks reached a quality

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Columbus, Ohio., Feb., 1925. (Art Division.)

[2] Ceramic Engineer, Pass & Seymour, Inc.

that has never since been equaled. And to the Roman potters the world is indebted for much of its advancement in clay-work.

Italian Pottery

After the fall of the Roman Empire but little trace remained of the arts practiced in the times of her prosperity. Such knowledge as that possessed by the potter cannot absolutely pass away, but so much of this knowledge is special and detailed that it is not a matter of wonder that both the Greek and Roman art disappeared.

Little is known of the potter's art in Italy after the fall of Rome till the 13th century. The traditions of the Roman potters appear to have been gradually lost, leaving behind only sufficient skill to make crude crocks for domestic use and to coat them, if required, with a crude yellowish lead glaze sometimes stained to a vivid green with copper oxide. Applied ornament of roughly modeled clay and scratched with designs were the chief decoration of such wares which were of the same class as the medieval pottery of England and the north of Europe. In the 12th and 13th centuries, however, contact with Asia Minor, Syria, Egypt and Spain, where ceramic skill had been highly developed in fresh directions, introduced into Italy as well as the rest of Europe, those superior wares characterized by a white surface decorated with bright colors under a brilliant transparent glaze, and beautified by metallic lusters. The Italian potters did not remain long unaffected by these influences.

But first let us glance at the native wares of Italy. These wares were made of coarse and often dark-red clay, coated with a white clay slip (a kind of pipe-clay) and covered with a crude lead glaze, either yellow or green. Later, while the vessel with its white clay coating was firm, yet soft enough, patterns were scratched or engraved through the white slip to the red body beneath. In the latter half of the 15th century a sudden advance took place in the coloring of this ware. Instead of simple glazes of uniform color, underglaze colors, green, purple, blue, brown and black, were applied in bold splashes under the straw colored glaze. This produced a rich and decorative effect by very simple means.

Majolica Ware

The name majolica ware indicates that the origin of the ware by this name was the island of Majorca, located in the Mediterranean off the east coast of Spain. More recently the view taken is that the knowledge of the manufacture was brought into Spain by the Moors who also settled in the Balearic Isles, and there practiced the potter's art. It has now been shown that a number of these pieces found in Italy are of Spanish origin.

The piece is covered with an enamel, the design then sketched and the

luster added. This consisted of a paste of clay containing the required oxide. The pieces were then given a low fire, a dull red heat. At this heat fuel producing smoke was added. When the pieces were cooled they were scrubbed, and underneath was the luster. This was due to the thinness of the film between the enamel and the paste containing the oxide. All the artists attempted this process, and thus the industry grew. The risks of the luster process were great, so that its use was relegated only to inferior wares, and then the process was relinquished and forgotten until its rediscovery in the latter 19th century. When one of the later majolica painters had spent weeks on the decoration of some vase or dish, it is not likely that he would care to expose it to any risks that could be avoided. Only the most experienced along the line of luster making were successful to any degree.

The Gubbio luster, as it is called, is best known to us through the works of Maestro Giorgio, whose distinctive luster is a magnificent ruby-red, unlike any other. In all probability the luster process was quickly abandoned on the fine painted majolica, because the increasing efforts to make a picture were discounted by so uncertain a process.

French Pottery

The pottery of medieval France was, for the most part, similar to that made generally in Europe. They were rudely shaped vessels of ordinary clay often ornamented and glazed with a yellow or brown lead glaze, or if coated with white slip, decorated with bright green glazes, and toward the end of the 15th century with grayish blue. The later specimens of this ware were extremely decorative.

Faience

French faience should be distinguished from dishes on the one hand and porcelain on the other. It is a low-fired, fancy pottery. When the French potters wanted to get some outside potters, they went to Faenza in Italy for men. Hence the ware that these men and their successors made was called "faience." The body of this ware is a creamy white, and the decoration is effected by inlaying fine lines and panels of darker colored clays, the whole being covered with a clear, soft glaze. The pieces show three periods of production: the crude period, the fine period in which the potter was successful, and the last stage when the pieces are overloaded with ornamentation.

During the 15th century came the distinctly French pottery—the Henri Duex ware, and the pottery of Bernard Palissy and his imitators. The Henri Duex or Oiron ware was believed to have been made by a librarian and his assistant for their patroness. Some years ago this theory was

disputed and the originator of the ware was said to be a potter of St. Porchaire. But all we know is that the ware dates back from the reign of Henry II, and that it was probably made somewhere near Oiron. The ware also shows marks that indicate that the maker knew something of bookbinding. The date of the production is believed to have been about 1524. This ware belongs to the faience class.

Palissy

"Bernard Palissy was a genius of original talent, and has gained a legendary rank as one of the great potters of the world, which his pottery does not warrant." He seems to have been trained as a glass painter. He was shown a cup which he took to be covered with white enamel—probably Chinese porcelain. He is supposed to have spent sixteen years in search for the white enamel. But when he settled down to make "Palissy Ware" he did nothing more than to carry out the perfection of the methods of the village pot makers of his own district. On a hard-fired red clay he made groups of molded plants, shells, fishes and reptiles. These he painted with crude green, brown and yellow colors, and glazed the whole with a well prepared lead glaze. This lead glaze was transparent, perhaps slightly yellow. An example of one of his pieces represents the bottom of a brook as he saw it. His colored glazes were beautifully rich and pure, and his style soon had numerous imitators.

All his productions are not of this class, however. He made some fine pieces with figures modeled in relief, and also some beautiful perforated dishes. His religious opinions led to his imprisonment, from which he was released after a time. But he was later taken to the Bastile where he died in 1590.

The succession of tin-glazed ware was resumed in France when the Duke of Nevers invited to that place a number of skilled artisans from Italy. The only thing in common between the wares of Faenza and Nevers was the use of tin in the glaze. The peculiar tint of blue and the exquisite purity of the white constitute the excellence of the faience of Nevers. This blue and white were the leading characteristics of this particular center.

Spanish Pottery

When the Arabs and Moors invaded Spain in the 8th and 12th centuries, they left their mark on the pottery of that country. There, as elsewhere, pottery was then being produced from the natural substances at hand. The material was simply what was found in the earth, and the preparation of the material for its use in pottery was crude. But in spite of all this, the pottery produced during that time has a subtle beauty, and it is impossible to duplicate it. For example, we know the chemical ingredients

of Cornwall stone, a mineral found in England and used extensively there. But we cannot put these ingredients together and make Cornwall stone. In the same way this pottery cannot be duplicated.

Majolica Ware—Its Origin

The nature of the work was in accordance with the location. When the Moors came into Spain they found an abundance of tin and lead. Here they began to use the natural substances for their pottery as before. So they began to experiment with the materials at hand. And the result was a white enamel. And with this their technique also changed. At first this pottery was called stanniferous faience, but it finally was called majolica faience, the name coming from the island of Majorca, near Spain, where some of this ware was produced.

The knowledge of this majolica faience spread along the southern coast of Europe, and finally to Italy. The time that this knowledge reached Italy was during the 16th century, the period of the Artistic Renaissance. During this period the pieces show elaborate styles of decoration, and also an occasional two firings. Up to this time the majority of the ware made by the Moors was only one fire.

Of the Hispano-Arabic pottery there seems to be no accurate knowledge, but of the Hispano-Moresque numerous examples remain. The tin enamel is of great beauty, and an important feature is made of colored lusters. A notable specimen of this ware is the famous Alhambra vase. The colors of the decoration are a pure blue enamel with a gold luster on a white ground. This vase was accurately copied by Theodore Deck of Paris, and the copy may be found in the Museum at South Kensington. Exportation of ware of this type doubtless laid the foundation of the industry in Italy, and led to the "Italian Majolica," which everywhere became famous.

Pottery of England

Throughout the Middle Ages the pottery made in England was, broadly speaking, only such as would be used by the lower classes. A few pieces of somewhat exceptional merit have been met with, but they are probably the occasional show pieces made by the humble peasant potter as a propitiatory token for his feudal lord or monastic overlord. Apart from a small number of exceptional pieces such as these, the pottery of England remained down to the 17th century practically indistinguishable from the common wares made all over the continent.

The pieces were made of ordinary clays, firing to various shades of buff, drab, brown and red; the material was coarsely prepared and capable, therefore, of receiving but little finish. The shapes were of the simplest, and such as were common in many countries during the early stages of the

potter's art. The glaze, when it occurs at all, is the simple lead glaze obtained by dusting powdered lead ore over the clay vessel before firing. On many pieces the glaze was colored by the accidental or intentional addition of the simpler metallic oxides, oxides of manganese, iron and copper. It was from these modest beginnings that the English potters of the 17th century gradually advanced.

Pottery of the Norman Period

Of the pottery of the Norman period but little has been said, and that because little has been known. Pottery was, indeed, ill suited to the roving propensities and wandering life of the Normans; besides they could hardly have brought into England an art almost forgotten in their own country. Our scanty knowledge of this period is confined to coarse pots and fragments found in excavations.

From these we learn that the pottery of this period consisted largely of pitchers, dishes, bowls and porringers; the bowls and dishes being used for drinking purposes as well as for placing cooked meats in; the pitchers for holding and carrying ale, meal and water to the table; and the porringers both for eating and cooking. The body of this Norman pottery was usually a coarse clay, and the vessels bear evidence in many instances of the wheel being used. The wheel was simply a revolving piece of wood, or other material, upon which the piece could be placed and built up by hand or tools. In color these vessels are sometimes of a reddish brown, others red, while others are nearly black; and many of the pitchers are either wholly or partially covered with a green or other glaze. Many pieces are quite devoid of ornament, and some are rather highly decorated.

Later these fictile productions began to assume a more ambitious range. The floors of churches and convents were paved with tile, inlaid with clays of various colors, and whereupon Gothic ornaments and even subjects of figures were depicted. These tiles represent a great variety of processes, being coated with glazes of different colors, embossed and pressed, and inlaid or painted with white clay.

German Pottery

The pottery of Central Europe in the 16th century may be classed as salt glazed stoneware. Before this time the people were engaged too much in warfare to have much of anything to do with the potter's art. Some accounts give the discovery of salt glazing as late as the 17th century. Stoneware glazed by salt no doubt derives its name from the close relation borne by the ware to stone itself. Hard and impervious, granular in texture, no better comparison could have been made.

The potter's wheel was used for the form itself, and the fanciful embossment was applied by means of small pieces of soft clay which had been

pressed into molds of the required pattern. Hitherto every substance used for glazing had been applied to the ware either in the clay or biscuit state, by dipping the piece in a vessel of glaze, or by painting the mixture over the ware. In stoneware the glaze is vaporized in the oven and unites itself with the clay at the same time. The potters of Germany or Flanders probably discovered this. The glaze used was simply common salt, which was thrown into the oven when at its greatest heat. Being volatilized, the salt entered into combination with the silica in the clay, forming a thin glassy coating all over the piece.

The main centers of the production of German stoneware lay in the district now known as Rheinish Prussia. Early in the 16th century fine work was produced at Seigburg, near Bonn. The clay used was commonly of the creamy white variety.

Porcelain

Now let us turn to the story of porcelain. This story has its beginning in Celestial China. Two thousand years before the Christian Era, the Chinese were great potters, and in 200 B.C. they were making a high grade porcelain. The high antiquity and perfection of the art of making porcelain by the Chinese, many years before any specimens of it found their way into Europe, are well authenticated by the older records of the Celestial Empire, which were brought to light by the early travelers.

Among the ancient arts of the second oldest nation of the earth, on the hazy edge of the old world, they found the Chinese making porcelain and jealously guarding the secret said to have been discovered during the Han dynasty, the Golden Age of China, which began in 206 B.C.

It is probable that Chinese porcelain first came under European eyes during the Crusades in Palestine and Syria. No doubt a limited number of specimens, mainly of celadon ware, found their way into Europe during the 14th and 15th centuries from Syria and Egypt, whither they were brought by the swaying camel train from Asia.

When Europeans, probably the Italians, first saw the Chinese ware, they called it porcelain from the resemblance of its polished surface to that of the Venus shell named Porcella, while the shell itself derived its appellation from the curved shape of its upper surface resembling the back of a "Porcella" or "Little Pig."

No considerable importation of Chinese porcelain took place until the Portuguese merchantmen succeeded in doubling the Cape in the 16th century and capturing the seaborne trade with the Far East. No sooner were the western potters familiar with the beautiful Oriental ware than they set out to imitate it; and at Venice in 1519, if not earlier, an artificial porcelain was produced.

Another account gives the date of the earliest specimens of European

imitation of porcelain as 1575. A few pieces are said to have survived from the productions of a kiln established at Florence. This famous Florentine porcelain was, however, entirely different in its nature and composition from that of the Chinese. It was made by mixing together an impure china clay, fine white sand and a large portion of glass. The pieces now seen in museums are rather thick and clumsy in substance; the glaze is not very brilliant; and the body is only moderately translucent. The decorations are always in underglaze blue, sometimes bright, sometimes rather gray, but always softened and a little run by the glaze. The designs almost invariably take the form of floral arabesques. It seems probable that this porcelain was an experimental one, abandoned as soon as the whim of its patron changed, and it cannot be said to have any influence on the subsequent course of European pottery.

Prof. Binns states that the entry of true porcelain into Europe was not until the early 18th century, when a chemist of Saxony discovered the secret.

Far greater development was reached in the pottery and porcelain of the later 17th and 18th centuries, which are not dealt with in this paper.

REFLECTIONS UPON ART AND MANUFACTURE[1]

By Ellsworth Woodward

ABSTRACT

The writer is struck by the interesting fact that in all manufactured articles in which there is an appeal to taste, those articles sell best and bring the highest return in money which possess the imprint of art. A truly beautiful thing increases rather than diminishes in value. Objects of pure utility, making no appeal to taste, are priced according to the exigencies of competition. They possess no added value, recognized as inherent in art. It would seem that the recognition of this intangible quality, which differentiates a beautiful and at the same time useful thing from that which is purely useful, but possesses no beauty, might be a subject of very great interest for a manufacturer. The great mass of the purchasing world is content to pay the higher price for the article which stimulates his imagination and affords him pleasure.

The other day I chanced upon a piece of old English earthenware among the miscellaneous offerings in a Royal Street shop of an antiquarian. I bought it on an irresistible impulse in spite of the price, which my sober judgment would have rejected as preposterous had a pitcher for merely practical use been in question. There ought to be something of suggestive value in this happening for makers of earthenware, for I am by no means a joyous spender of money.

The point is, this little pitcher is lovely. It affords me delight when I see it out of all proportion to the use it has as a container. I would not

[1] Recd. Jan. 23, 1925. Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, Feb. 1925. (Art Division.)

part with it even at a premium. Surely there is a stimulating idea in this if only the writer could make it clear and be credited at the same time as a sober citizen seeking only to be useful to that great body of workers whose craft he so much admires.

As a life long seeker and follower of the Ariadne thread of beauty through all the works of Man, it has been my privilege to linger as a student in practically all the museum collections of the world. In all of these ceramics has an honored place, and so arranged that one sees how the unconscious play of the potter's artistic faculties creating a thing of beauty while observing the limitations set by use, changes to the conscious, ordered style of craftsmen stimulated by the approval and rewards of kings. One started on a tour of contemplative study, soon discovers that ceramic art has always been a responsive medium for the expression of beauty. Ambitious rulers have realized its possibilities and established great laboratories of artistic endeavor under royal patronage, not always with the hope of financial profit, but as a means of exchange as friendly compliment or in smoothing diplomatic relations. Pottery and porcelain were precious things possessing under these conditions a value immeasurably beyond utility of service. Almost fabulous value it would seem sometimes, for private collector and museum curator openly gloat over their treasures and tell us without apology the prices at which they are quoted.

Finally, as our studies progress, we begin to understand and approve the justice of the high esteem in which certain designs and colors are held and are ready to inquire into the mystery. Why do collectors struggle for possession of certain examples of style and period or the work of an individual craftsman, while other wares remain merely crockery to the end of their existence and pass unmourned into the limbo of the trash-dump?

Your inquiry will lead you inevitably to art as the explanation. Art which combines form and color into a whole—the whole which is a joy forever. Science which guides us so definitely today was, in the past when many or perhaps most beautiful triumphs of the art were made, only present as an accumulation of experience not understood but recognized as operative; for if the combination was inaccurate heartbreaking loss was the penalty. But, and this is the point, the incomparable value of beauty was there in rich abundance. This was no accident for the craftsman was an artist.

It is a commonplace of knowledge that our age is one of scientific achievement beyond all competition from other forms of intellectual endeavor. From this unquestioned state has grown a quite natural pride and preoccupation to the exclusion of appreciation and even of the power to understand other and greater forces.

It is true, though rarely comprehended and perhaps difficult of comprehension, that the only permanent thing in this changing world is spirit.

Things of pure utility serve their purpose, wear out and are forgotten. Those other things to which have been added the mysterious quality of beauty are cherished even in their shattered old age. The foregoing is a statement of sober fact, and yet so holden are our eyes in this age of glittering, material achievement that we refuse to understand.

My parable reciting my encounter with the little pitcher with green leaves floating on a sea of deepest blue will be understood by a few. I am hoping that some young, courageous manufacturer of ceramic ware in quantity production, may also understand and understanding put all to the hazard. With good sense as well as courage, he could become the merchant prince of his age. Really art is the most practical asset of the manufacturer, even when misused; when applied in full measure of skill and understanding the product is without rival.

NEWCOMB POTTERY
NEW ORLEANS, LA.

COMMON STONEWARE DECORATED BY THE CHINA PAINTER'S PROCESS[1]

BY ARTHUR M. WHITE

The old saying that "it is hard to teach an old dog new tricks" has probably been considerably overworked, but no doubt contains a germ of truth, and used with a reverse English, might apply as an excuse for this paper, which is offered without any apology at the instance of Prof. Cox of the Iowa State Agricultural College, who was good enough to make some kind remarks concerning some pieces of decorative pottery produced by the writer several years ago, who at that time was actively interested in the manufacture of stoneware at Fort Dodge, Iowa. Referring to our observation would say that to one who has spent most of his earlier years in mastering the various problems as they pertain to the manufacturing of clay goods and having the inspiration of three generations of ancestors who were engaged in the same occupation, one finds it almost impossible to forget that early training; hence this paper.

For the benefit of those who might not be familiar with the manufacture of stoneware, it might be said that stoneware has been defined as that kind of pottery which is made from a natural clay and whose firing and glazing is accomplished in one operation. It is always glazed and generally it is vitrified in body texture.

The pieces produced at that time were made from the stoneware clays found in abundance in this locality. The clay was prepared by washing in the usual manner and the articles were mostly hand-turned and consisted of pitchers, jugs, vases, tobacco jars, steins, etc., also some medal-

[1] Presented at the Annual Meeting of the AMERICAN CERAMIC SOCIETY, Columbus, Ohio, Feb., 1925. (Art Division.)

lions, which were molded. The designs were applied to the dry or green ware in outline, free hand, and then scratched out with a pointed instrument; all rough edges were carefully smoothed out. The ware was then carefully dried and fired once as bisque ware, along with other stoneware.

After the initial firing the pieces were carefully gone over and all imperfections removed as far as possible, and treated to the regular dip of transparent glaze, which retained the natural straw color of the clay, after the second firing. Regular china colors were applied by Mrs. White, who had received training as a china painter, and who was responsible for all the decorative effects. She also modeled some of the handles. The last and final firing was accomplished in an oil burning studio china kiln.

These wares, having been subjected to the high temperatures of a stoneware kiln, were practically vitrified, and when struck, gave out a sharp, metallic ring, and were both grease and acid proof. Some good, underglaze effects were produced by using a black oxide of cobalt, with a suitable flux for the designs, and then applying the glaze and firing only once.

It can readily be seen that the beauty of this ware is mainly dependent on the artistic ability of the decorator, as well as the selection of designs suited to the size and shape of the pieces, in order to secure that harmony of color texture and line so pleasing to the connoisseur.

The pottery above referred to was destroyed by fire some years ago and the work of the writer along this line necessarily terminated and about all that is left of these experiences are some very pleasant recollections and a modest collection of ware. If the experiences of the writer, as outlined in this rather brief and hastily composed paper, have been honored with your interest and attention, I shall feel well paid for the effort.

FORT DODGE, IOWA

DISCUSSION ON "OBSERVATIONS ON PINHOLING IN CAST WARE"[1]

PAUL E. COX:[2] Professor Binns taught his students to paint the molds with the slip before pouring the slip into the molds when casting wares for use as test pieces in the laboratories. This process prevented pinholing. I accepted this process as one in common use in English plants, since Prof. Binns had at that time but lately come from the Royal Worcester Porcelain Factory. I know that a little work with a brush saves much patching of surfaces in the casting of small vase forms.

While I cannot formulate an answer to Mr. Hemphill's questions, I would say that a painstaking review of the literature to date and some

[1] Paper by R. W. Hemphill, *Jour. Amer. Ceram. Soc.*, **8** [3], 145 (1925).

[2] Iowa State College, Ames, Iowa.

laboratory work in the plant and under plant conditions would yield the answers. Determinations of the properties of the clays and other raw materials of the slips in question would point the way.

W. KEITH MCAFEE:[1] I will not attempt to answer the question asked in the last part of Mr. Hemphill's excellent paper. There are several points I would like to raise, however.

Mold condition, no doubt, has a very great deal to do with pinholing. As Mr. Hemphill points out, damp molds will increase this trouble. Cold molds and new molds are also bad in this respect. The latter probably because of the slick surface, which can be largely counteracted by properly sponging the casting surfaces. "Soft" molds tend to eliminate pinholes, but are usually impractical.

It seems to me that these conditions have to do more with the cure of pinholes than the prevention. We mean by pinholes, I take it, small round holes penetrating the surface of ware to varying depths, and probably caused by trapped air, and possibly in some cases, by shrinkage. Assuming that these are caused, for the most part at least, by trapped air, either due to incorrect pouring of the molds or air in the slip itself, the condition of the molds will either help to eliminate this air, or hold it at the surface, as pointed out by the author.

We have found that the rate of, and method of, pouring molds has a great deal to do with this trouble. The slip should not splash, should be poured in a slow, even stream and, where possible, allow the mold to fill from the bottom up.

A great deal of trouble was experienced with pinholing about a year ago, and investigation disclosed several sources of air in our slip distributing system. In our system, the finished slip is run from the lawns to storage cisterns by gravity. It is pumped from there to open tanks on the roof of the casting shop. Both the cisterns and slip tanks are provided with agitators. The slip flows by gravity through pipes to the various casting benches where it is drawn off through hose and introduced directly into the molds.

A worn stopcock on the suction side of the slip pump was replaced. The slip was fed to the tanks on the roof from the top and dropped some distance into the tanks when they were empty. The piping was changed to introduce the slip from the bottom. All the agitators were slowed up so that there was no splashing at any time. The blades of the agitators were warped slightly to give the slip an upward motion as they revolved.

These changes immediately brought about a great improvement. The casters were required to draw off a bucket of slip immediately before they

[1] Cambridge Sanitary Manufacturing Co., Cambridge, Ohio.

started to pour, and bleeder valves were placed at various points on the slip pipes. These valves are opened before pouring starts, and air allowed to blow off until slip begins to flow. It is surprising how much air can be drawn off in this way.

One of the most important remedies for pinholes is the method of finishing. Mr. Hemphill brings out this point. I sometimes think that all ware has some pinholes which will invariably show up if the finishing is not correctly done and at the right time. This point has been lately brought forcibly to our attention. We stick the rims on our closet bowls with a roll of pugged clay. If this is not worked down properly, it will be fairly peppered with pin holes. They are very fine, and practically impossible to detect either in the green or biscuit stage, and only show up in the gloss ware. This seems to be purely a question of finishing.

Pinholing is a trouble everyone seems to have more or less. They are sometimes nearly $^1/_{16}$ inch in diameter and run clear through a piece of ware $^1/_2$ inch thick. They seem to be most prevalent in single cast ware, or hollow cast ware, which is nearly the same thing.

DISCUSSION ON "THE ELECTRIC BRASS FURNACE REFRACTORY SITUATION"[1]

MEMBER: What watt-loss is permissible before one would consider replacing the lining? What is the proportion of the energy lost through the refractories as compared to the total energy consumed? In other words how do you know when to tear the lining out?

E. L. MACK: A computation of that would depend largely upon conditions of melting whether melting eight hours or twenty-four and what you are melting. It would be hard to say offhand. We can say in a general way that you get to a point in lining life where the energy loss through the refractories is so great that the *average energy consumption over the whole period of lining life* will be 10 or 15% higher than that obtained in the first heats on a new lining. This is caused by increased heat conductivity of the lining due to metal penetration. Obviously a point exists at which it will pay to renew the lining even though the old one is in good mechanical condition. Beyond this point the cost of a new lining is not being saved; it is being paid to the central station for warming the atmosphere in the vicinity of the furnace. For any particular case the locating of this point should be a matter of experiment based upon complete melting data obtained under average foundry conditions.

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[1] H. W. Gillett and E. L. Mack, *Jour. Amer. Ceram. Soc.*, **7** [4], 288(1924). Discussion presented at Atlantic City Meeting, Feb., 1924. (Refractories Division.)

CHAIRMAN LYON: This paper is an illustration of what the metallurgist has in mind when he says we are in need of better refractories. As you probably understand it may be possible for the metallurgist to develop a process but if he has not a refractory that will stand the requirements right there he stops. One of the objects of this discussion is to acquaint the ceramic engineer and the manufacturer of refractories with the metallurgical requirements of refractories.

MR. CROSBY: In the application to the non-ferrous melting industry of the Detroit electric furnace we have in the past encountered a great many refractory problems. Those problems seem as far as the non-ferrous industry is concerned to be thoroughly solved. Metal production on the order of 2,500,000 pounds per lining is not at all unusual and we will average one and one-half million pounds on refractories on red brass alloys; on yellow brass alloys the figures show higher refractory life than most others.

We have furnaces in satisfactory operation on nickel-silver and have been able to show on the manufacture of synthetic gray iron a lining life comparable to that of the cupola or similar metallurgical equipment which is fairly a good result. For the brass furnaces we are using refractories from two or three standard sources. These are of the highly aluminous class and are made up in standard blocks. In fact that is perhaps the solution to our lining problems. We have made these blocks in various sizes to fit the various furnaces. At one time I was imbued with the idea that I would like to have a one-piece cylindrical lining and still would if I could get a ceramist that would give me one which would be satisfactory. We went a step too far in that direction, however, by making our blocks so large that they cracked, and have gone back to smaller sizes. The furnace size in the 750-pound Detroit furnace for instance is a circle block which is about ten inches square and four and one-half inches thick.

A great deal has been done in the development of patching material which also helps us to improve our lining life. Scrap metal contains considerable siliceous and other non-metallic material and the erosion and chemical reaction tend to chew up the lining rapidly. We believe one of the peculiar advantages of the moving indirect-arc furnace is that it is extremely easy to patch.

Our furnace is nothing more or less than a hollow cylinder and is so designed that patching may be applied readily either from the electrode portholes or from the door.

We would be highly interested, in fact the thing that is attracting more attention at the present time from our engineering department than anything else is the development of a refractory lining for our furnace for use in the manufacture of synthetic gray iron.

It is rather difficult to make a magnesite lining stick in our type of furnace and we have tried a great many mixes which have been suggested by several prominent ceramists with very unsatisfactory results. We would be intensely interested in a refractory which could be applied in a cylindrical furnace readily and stand up under the melting of iron borings and turnings. I believe there is a tremendous market for that type of equipment. In fact, I am positive that we have a demand for several furnaces that could be supplied immediately if we felt there was a refractory which we could unhesitatingly state would last from four to five hundred heats on gray iron. Unfortunately I know of no such refractory. I am confident that so far as refractories for non-ferrous work are concerned our troubles are behind us. They have long since been solved for our furnaces.

D. A. LYON (Chairman): The field of usefulness of the induction furnace could be much extended if suitable refractories were developed for such a furnace. So far the consumer has done the talking on this subject. The ceramist should have something to say. At a similar symposium last year at Pittsburgh those of you who were there will remember that the refractories people did all the talking and we could not get the consumer to say anything. The metallurgical industry today and, especially the electric furnace phase of it, is up against it so to speak for refractories that with meet the requirements. As Dr. Mack said, what is needed is not merely a refractory that will stand high temperatures. The requirements are very much more than that.

E. L. MACK: There is one other thing I would like to hear discussed. That is the possibility of producing what, for want of a better name, we call a "graded or laminated" refractory. I think Dr. Gillett has previously talked about this possibility before this and other societies. The idea is to attempt to make use at the same time of the excellent refractory properties of carborundum and the good mechanical and thermal properties of fire clay by working out a refractory having a continuous variation in composition from pure fire clay on one face to bonded carborundum on the opposite face. Actually this would very likely work out as a piece built up from layers of increasing carborundum content as the working face is approached.

It is recognized that the ceramic problems to be encountered in the production of such a refractory would be stiff ones but it is felt that the usefulness of the product would justify the effort. A successful development along this line would make available a refractory of fairly good thermal resistance, good mechanical properties, and superior chemical resistance. It would have a certain field of application awaiting it in the brass-melting industry and very likely additional fields in other metallurgical industries, with which I am not so familiar.

DISCUSSION ON "PLASTIC PROPERTIES OF ENAMEL SLIP"[1]

R. D. COOKE: The mobility increases in a linear manner with the solid content and has a concentration of zero mobility. At the concentration of zero yield point the mixture passes from a liquid to a solid. These methods should give valuable results in determining the suitable clays for enameling purposes with reference to their ability to suspend the enamel and provide good operating consistency.

H. F. STALEY: Mr. Cooke has touched on a rather vital point in regard to enamels. The determining or measuring in quantity the properties of enamel clays is one of the most difficult and obtuse problems we have. About the only way we have at the present time of trying out a clay is to put it in the enamel and if it works, it works, and if it does not work, we set it aside and keep it as an exhibit.

Mr. Cooke in his method states that if the clay does not work he not only finds out why it fails to work but he may be able to add something which will make it work. Therefore this paper is of real practical value to the enamelers.

R. R. DANIELSON: Do you make the determinations on the enamel slip as it is used in the shop or do you have to thin it down?

MR. COOKE: It is made on the enamel as it is used.

R. R. DANIELSON: I think Mr. Cooke has done a mighty fine piece of work. Those of us who tried to use the old apparatus for making determinations for the setting up of enamels have found it of practically no value. The Bureau has done considerable work on clays. They have had the problem whether the Bingham apparatus could be used. Because of the comparative coarseness of the enamel particles they could do nothing with it. Mr. Cooke has been very ingenious in devising an apparatus which gets around the objection of the present Bingham apparatus.

R. D. LANDRUM: This gives us another method of making a standard for our shop practice.

There are some hundred places in the enameling process where things can go wrong. And for those one hundred places we have only four or five standards, because we have only four or five things that we can actually measure. In the manufacture of table tops we not only have to put the enamel on, but we have to put it on quickly. Production is essential. We do not want to take the time to spray. Our idea would be simply to have a machine that would put this table top through the enamel, drain and dry it and then on through the furnace. Our need is a continuous process.

What is the defeating factor in having the slip the same today, to-

[1] R. D. Cooke, *Jour. Amer. Ceram. Soc.*, 7 [9], 651(1924). Discussion presented at the Atlantic City Meeting, Feb., 1924. (Enamel Division.)

morrow and the next day? Five table tops dipped by the same girl in exactly the same tank will be found to have a variation of 25% in the weight of enamel on the tops.

Mr. Cooke has given a method and a machine that any enameler can rig up and interpret the results. He can find how to make that slip always work the same. With these ideas we can find a method of keeping the procedure uniform.

B. T. SWEELY: There is just one phase which Mr. Cooke has brought out but on which no one has as yet touched and which is of vital importance to the man who is spraying ware. You will find that the sprayed piece of ware leaving one operator is perfectly smooth while on that from another operator the enamel will pile up no matter how you set that gun. In other words instead of being a perfectly smooth coat it looks rough as though the operator had held his gun too close. It makes no difference where you hold the gun you will get that effect.

I believe the yield point as Mr. Cooke describes it in this test is the key to that situation—the thing that we have all been seeking, trying to get—a uniform and smooth coat of enamel on a piece of ware under the average spraying condition.

In my own shop that is one of the most troublesome things with which I have to deal. We set the enamel in the time-honored practice of sticking a finger into it. Look at your cull pile and you will see why such a test is no test at all.

The question of keeping your slips under control is a very acute problem in the shop. I worked for some eight months trying to standardize slips. I never succeeded in doing it. I was trying to standardize viscosity. I think Mr. Cooke has at least hit on something that will give us a real start on the question of standardizing our enamel.

H. F. STALEY: This question is of interest not only to the wet coat enamelers but also to those who do dry coat enameling, because in getting a uniform ground coat on the casting either by spraying or slushing or pouring enamel, the ground coat is very liable to run down and collect in heavy beads at edges and in certain other spots, which causes blistering.

ART DIVISION QUESTION BOX

MARGARET KELLY CABLE, EDITOR

In conducting a Question Box, it is the aim of the Art Division to serve not only the members of its own individual division, but also the members of any of the other divisions to whom it may be of service.

This being a new venture for the Art Division, we do not know the best and wisest way to proceed. We are going to begin, however, by

publishing from month to month a list of contributed questions with a discussion of one or more, as space permits, by some well-informed person.

Our initial list of questions is rather meager but we wish to get going. We want you to know *first* that there is such a thing as an Art Division Question Box and *second*, we want you to help make it a success by allowing us to serve you. The true measure of our success will be in direct proportion to the real value of our service.

Please do not hesitate to send in that perplexing question, or any new or helpful suggestion. Discuss it yourself and we will endeavor to supplement your discussion with the viewpoint of others.

Address all communications to Margaret Kelly Cable, University Station, Grand Forks, North Dakota.

Questions

1. What is the best way of preparing clay for a school having no clay washing and clay preparing equipment?

2. Is there a light burning clay which burns dense at cone 1, for example, and where may it be bought prepared for studio use?

3. Where do such schools as are listed below purchase their clays? Are they bought wet or dry?

The Lewis Institute and the Art Institute of Chicago, the Cleveland School of Art, the Museum School of Industrial Art, Philadelphia, the Museum School of Fine Arts, St. Louis, the Newcomb School of Art, New Orleans, Schenley High School, Pittsburgh, the Normal Art Department, University of Wisconsin, and the University of North Dakota.

4. I have had difficulty since the war in securing flat potter's sponges. Where may they be obtained?

5. What is the relative difference in the cost of purchasing glazes ready for use and making up one's own, provided one has the equipment?

6. Is there any way that a porous biscuit body may be made waterproof except by glazing? For example, many small schools have no kilns or firing facilities near at hand and yet would like to render the pieces, fashioned of local clays by the grade school children, waterproof. These pieces could be biscuited at a low temperature in an open fire much as primitive wares are baked. The teacher from whom the inquiry comes would like to know if there is any simple method of treatment or preparation which could be applied to the inside of such wares to make them waterproof?

Reply to Question 1. By FREDERICK H. RHEAD.—I would suggest the installation of a simple, 25-gallon barrel churn, costing about $12.00. A small motor would cost from $15.00 to $20.00. The churn can be driven to operate about 55 revolutions per minute.

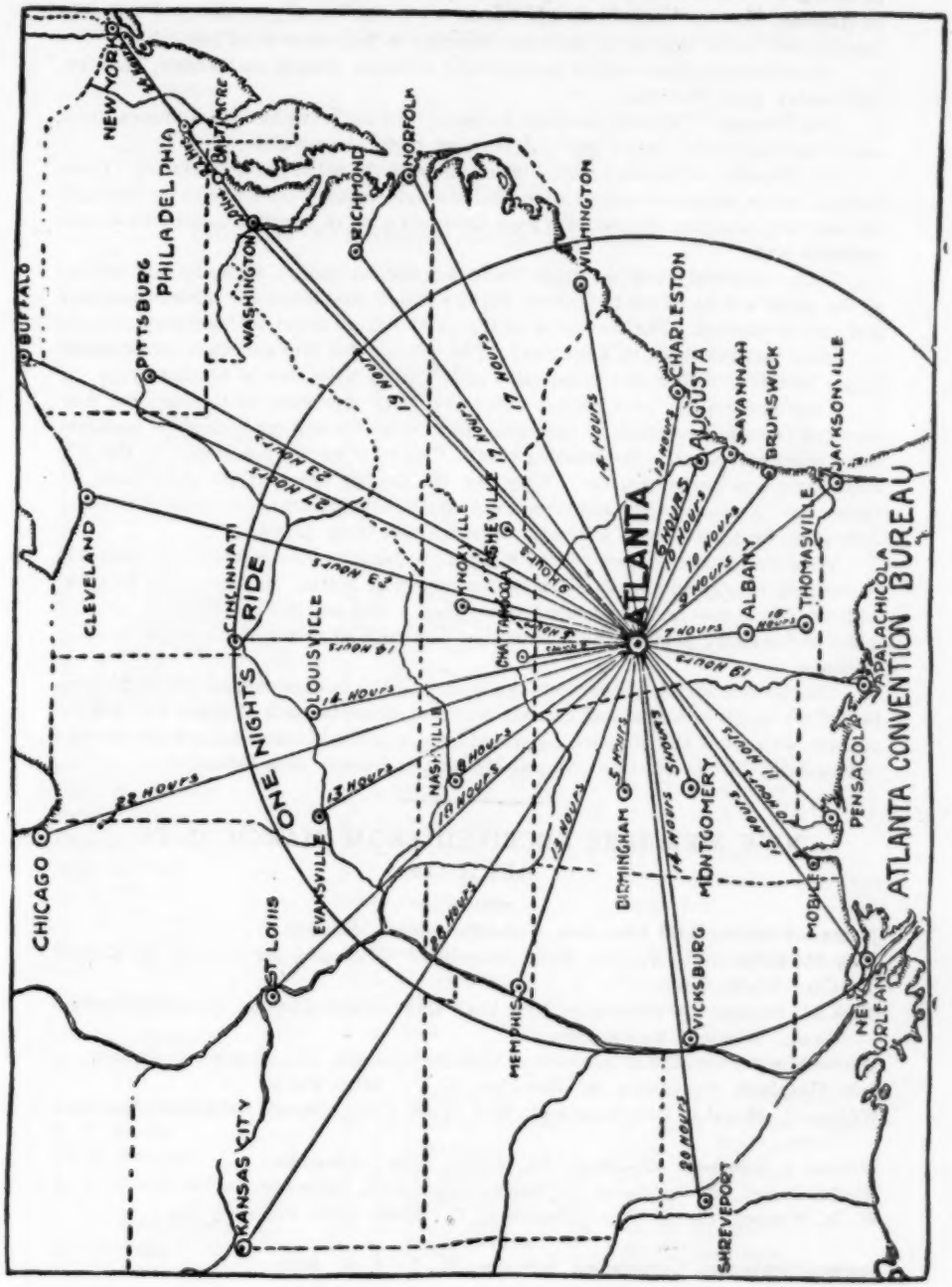
The clay mixed with about 50% of water would be placed in the churn and operated for four or five hours. The resulting slip would be run through a 60-mesh sieve and then poured in plaster troughs until the surplus water was absorbed. The clay would then be wedged or kneaded to an even consistency.

Such a process could be reduced to a mere routine. Students should assist in this work not only as a matter of convenience but they should know how to prepare clay.

The 25-gallon churn will mix approximately 100 pounds of clay and as this can be done in about four hours, the needs of an average size school can easily be met.

ACTIVITIES OF THE SOCIETY

OUR GEORGIA MEETING



February 8–13 inclusive, 1926, is the time the members of this SOCIETY will spend in Georgia. Words from the Georgian ceramists and from the Chambers of Commerce in Atlanta, Macon, Gordon and MacIntyre are to the effect that nothing humanly possible will be left undone to make our Meeting in their state most profitable.

The technical sessions will be held in Hotel Biltmore, Atlanta on Monday, Tuesday, Wednesday and Thursday.

The Woman's Club has promised a regular "cut up" evening with a musical farce and a dancing party "what am." A banquet royal also awaits.

On Thursday afternoon a special train will move the entire party to Macon. Comfortable hotels, modern in every respect and of ample capacity will house us for the night but not until after the Macon folks have shown us a bit of banquet hospitality in true southern style.

Friday morning early we again board our special and go eastward. A portion of the party will go direct to Stevens Pottery where they make fire brick, sewer pipe and clay specialties. The remainder of the party will go direct to MacIntyre.

Have you ever been to Klondyke? You will on this trip and that too with the Edgar brothers. Other clay preparation plants, most novel, are in MacIntyre.

Then about noon both parties will travel back westward to Gordon, the four cornered ceramic metropolis of Georgia. In Gordon we will see a modern porcelain brick plant and several clay washing plants, that is, if we are not loaded to the gills with barbecued partridges, etc. They say the Gordon crackers are right there on barbecues. Even now their mouths are watering in anticipation of our being with them. And some brick plant you will say. Bauxites and clays galore.

Then Friday evening our special will take us back to Macon where we again will be received royally and again enjoy their comfortable hotels. Saturday will be spent with the Maconians and some spenders are they. You will have a chance to see clay mines and washing plants and the extensive clay working plants of our fellow member Dunwody.

This hurried sketch of the week as planned by the Georgians does not make mention of the many historical and ceramic points of interests, each of which you will remember with profit and pleasure. A grand time, a profitable meeting and the extreme of hospitality awaits us at our Annual Meeting in Georgia next February.

NEW MEMBERS RECEIVED FROM MARCH 15 TO APRIL 15

PERSONAL

J. Atwood Austin, 1942 Iuka Ave., Columbus, Ohio. Student.

Willi M. Cohn, P. O. B. 161, Haifa, Palestine. Managing Director of the Kishon Clay Works, Ltd.

Clark M. Dennis, 233 Broadway, New York City. Chief Chemist, Technical Service Dept., American Trona Corp.

Myrtle Meritt French, Art Institute of Chicago, Chicago, Ill. Teacher of Pottery.

Jane Hoagland, 206 Quincy St., Brooklyn, N. Y. Artist Potter.

William J. Murphy, 233 Broadway, New York City. Borax Salesman, American Trona Corp.

William J. Spielman, 229 Hamer St., Clyde, Ohio. Enameler.

Walter Steger, Im Eichkamp 46, Berlin, Grunewald, Germany.

W. D. Woolley, Carey, Ohio. President, The Carey Ohio Porcelain Co.

CORPORATION

Ingram-Richardson Corporation, Bayonne, N. J. J. R. Burt.

Membership Workers' Record

	Personal	Corporation
R. D. Landrum		1
Mary G. Sheerer	2	
Ira E. Sproat	1	
Office	6	
Total	9	1

LIST OF STANDING COMMITTEES, 1925-26

Publication
Forrest K. Pence, *Chairman*
Francis C. Flint
Miner L. Hartmann
W. E. Dornbach

Rules
L. E. Barringer, *Chairman*
M. F. Beecher
J. D. Whitmer
S. R. Scholes
W. J. Stephani
Arthur Baggs
R. R. Danielson
W. D. Richardson
W. E. Dornbach
W. A. Hull
E. H. Fritz

Membership
————*Chairman*
Fred B. Ortman
Hewitt Wilson
Charles F. Geiger
Ray T. Stull
R. A. Weaver
J. M. Hammer
R. A. Horning
Geo. P. Fackt
I. E. Sproat

Standards
R. F. Geller, *Chairman*

Definitions
A. S. Watts
M. F. Beecher
J. S. McDowell

Raw Materials
D. W. Ross
M. C. Booze
E. C. Hill

Tests
C. F. Binns
E. P. Poste
R. F. Brenner
A. V. Henry
G. A. Bole
C. W. Hill
Geo. Sladek

Products
F. H. Rhead
A. E. Williams
Hewitt Wilson
W. L. Howat
Robt. Twells, Jr.

Sections and Divisions
A. Silverman, *Chairman*
E. P. Poste
A. F. Hottinger
F. L. Steinhoff
F. T. Owens
Mary G. Sheerer
M. E. Manson
A. Silverman
John D. Martin
C. E. Bales
E. C. Hill
F. H. Riddle

Research
W. M. Clark, *Chairman*
A. V. Bleininger
A. R. Payne
R. L. Clare
R. R. Danielson
F. H. Rhead
H. F. Staley
E. W. Washburn
F. G. Jackson
R. F. Ferguson
H. G. Schurecht
A. V. Bleininger

Papers and Program
Ross C. Purdy, *Chairman*
H. Clinton Baldwin
H. G. Wolfram
A. N. Finn
A. P. Potts
L. C. Hewitt
G. M. Tucker
F. H. Rhead

Geological Survey
S. L. Galpin, *Chairman*
H. Ries
A. M. Campbell
W. G. Worcester
G. A. Bole

Data
C. W. Parmelee, *Chairman*
H. S. Kirk
T. D. Hartshorn
J. W. Cruikshank
R. E. Arnold
D. W. Ross
T. A. Klinefelter
E. Schramm

Ceramic Education
W. Keith McAfee, *Chairman*
Edna P. Carson
R. D. Landrum
H. W. Hess
H. R. Straight
A. F. Hottinger

PERSONAL NOTES

Y. R. Anderson, formerly of Young, Saskatchewan, Canada has moved to St. Louis, Mo., where he is employed by the Evens & Howard Fire Brick Co.

Randolph H. Barnard of the Illinois Glass Co. of Alton, Illinois has been transferred to the Gas City, Ind. plant.

Richard S. Bradley of Bement, Illinois has moved to Mexico, Mo.

George H. Duncombe of Columbus, Ohio has recently become affiliated with Mellon Institute, Pittsburgh, Pa.

Roland J. Gouin, Plant Chemist for the Illinois Glass Co. of Alton, Illinois has moved to Claremont, N. H.

Victor V. Kelsey has moved from Knoxville, Tenn. to Washington, D. C.

R. D. Landrum, past president of the SOCIETY is now identified with the Titanium Alloy Mfg. Co., Tenbusch Bldg., 6007 Euclid Ave., Cleveland, Ohio.

F. A. McCann, who has been affiliated with Mellon Institute, Pittsburgh, Pa., is now with the Pacific Clay Products, Inc., Los Angeles, Calif.

J. G. Phillips, who has been connected with the Research Laboratories of the Standard Oil Co., is located at the U. S. Bureau of Mines, Columbus, Ohio.

Fred W. Runge, Chemist for the Josiah Anstice & Co., Inc., Rochester, N. Y., is now located with the Ferro Enameling Co., Cleveland, Ohio.

Victor N. Yingling has moved from Columbus, Ohio to 318 N. Duke St., Lancaster, Pa.

LOCAL SECTION NEWS

Baltimore-Washington Section[1]

The fourth and last meeting of the Baltimore-Washington Section for the 1924–25 season was held at 7.00 P.M. Saturday, April 7th, 1925, in Washington, D. C. The usual dinner was enjoyed.

Dr. Kurd Endell of the Technische Hochschule, of Berlin, Germany gave a paper on "The Thermal Expansivity of Refractories." Dr. Endell gave us an insight into some of the peculiarities of expansion which take place in some refractories.

Dr. J. W. Greig of the Geophysical Laboratory, in his paper on "The Formation of Mullite from Cyanite, Andalusite and Sillimanite" showed that the formation of mullite takes place at definite temperatures for these materials.

Dr. Endell and Dr. Greig used lantern slides to illustrate their papers.

These two speakers were followed by Mr. H. F. Staley of the Metal and Thermit Corp. Mr. Staley addressed us on "Pottery and Enameling Practice on the Pacific Coast." His explanation of some of the ingenious devices used by our Western brothers was somewhat handicapped by the lack of a blackboard, but he easily overcame this and made us understand the workings of these devices.

Following the speakers there was an election of officers for 1925–26. The following were elected:

R. R. Fusselbaugh, Chairman, Baltimore Enamel & Novelty Co.
P. H. Bates, Vice-Chairman, Bureau of Standards
D. H. Fuller, Secy. and Treas., Bureau of Standards
Karl Langenbeck, Councillor, Bureau of Standards

After the election the meeting adjourned. The next meeting to be held in Baltimore, on October 3rd, 1925.

[1] Reardon Fusselbaugh, Secy.

Chicago Section Meeting

The members of the Chicago Section held their April meeting on the 14th at the club rooms of the Western Society of Engineers. The success of the meeting was immense and the members proved that a local section can produce a program equal in caliber to the Annual Meetings of the SOCIETY. The following papers were presented at the afternoon session and each one was followed by a spirited discussion:

1. "Role of Air in Plastics," by Harry Spurrier.
2. "Manufacture of Eversharp Leads," by Robert Back.
3. "Ceramic Problems in the Manufacture of Telephone Equipment," by H. T. Bellamy.
4. "Data on the Operation of an Oil-Fired Frit Furnace," by B. S. Radcliffe.
5. "New Type of Oxy-Acetylene Fusion Furnace, with Notes on the Behavior of Refractories at Cone 40," by A. F. Gorton and W. H. Groves.
6. "Research Work in Progress at the Department of Ceramic Engineering, University of Illinois," by C. W. Parmelee.

Forty-two were present at the dinner at the Chicago Engineers Club. In the evening the following papers were presented:

1. "Manufacture of Molded Insulation," illustrated with two reels of motion pictures, by R. C. Shuey.
2. "Manufacture of Fine China" (motion pictures), by W. W. Wilkins.

R. D. Landrum represented the Board of Trustees and spoke briefly congratulating the members on their record meeting. The motion pictures films which were shown proved very entertaining.

CHAIRMAN OF ART DIVISION A DELEGATE TO THE PARIS EXPOSITION

A number of ceramists intimately connected with the Exposition of Modern Decorative and Industrial Art, which opens in Paris, in May, will accompany the commission appointed by Secretary Herbert Hoover. Mary G. Sheerer of H. Sophie Newcomb Memorial, will represent the AMERICAN CERAMIC SOCIETY.

Interest in the arts shown at this exposition has been greatly fostered by the attention given to it by Secretary Herbert Hoover who appointed a commission to head the delegation, comprising Dr. Charles R. Richards, president of the American Association of Museums, as chairman, Mr. Henry Creange, the winner of the Friedsam Art and Industry Medal, and Frank G. Holmes of the Lenox potteries in Trenton. The commission appointed Edward L. Bernays, counsel on public relations, as an associate member.

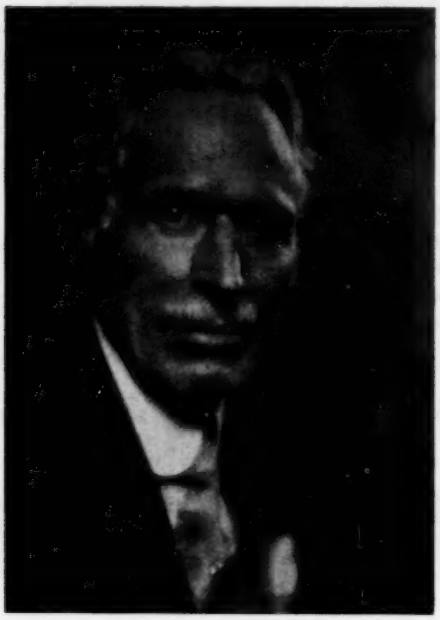
In officially recognizing the importance of this exposition, Secretary Hoover has taken the first step in the government interest in these industrial arts. He called upon the commission to report on such features of the exposition and phases of the individual groups of exhibits, as may be of interest and value to American manufacturers.

OBITUARIES

Willis E. Cunning

Willis E. Cunning, president of the West End Pottery Company, East Liverpool, Ohio, died on April 4 at the age of sixty-three. Mr. Cunning had long been a member

of the AMERICAN CERAMIC SOCIETY and since 1920 had been corporation representative for this company.



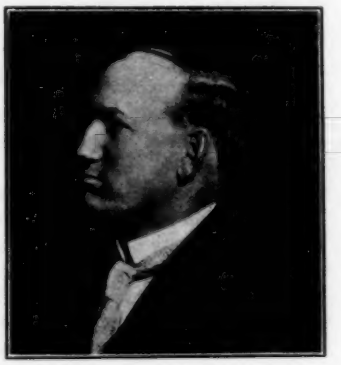
WILLIAM SHAW GEORGE

William Shaw George

William Shaw George, President of the W. S. George Potteries Co., East Palestine, Ohio, and corporation member of the AMERICAN CERAMIC SOCIETY, died in New York City, April 12, 1925. Mr. George was born in East Liverpool, Ohio, March 21, 1865. In 1898, he left the employ of the Ohio China Co., as decorator, to take over the management of the East Palestine Pottery Co.'s plant, which is now No. 4 plant of the W. S. George Potteries. Other plants of this company are located at Canonsburg and Kittanning.

Richard R. Hice

Richard R. Hice died at his home in Beaver, Penna. at the age of sixty. He was a charter member of the AMERICAN CERAMIC SOCIETY and president of same during 1915. Mr. Hice graduated from Geneva College, at Beaver Falls, in 1880 and he was engaged in brick manufacturing for a number of years. In more recent years he devoted a great deal of time to geological survey work in Pennsylvania. He was a large contributor to the Transactions of the SOCIETY.



RICHARD R. HICE

William Henry Grueby

Word has been received of the death of William Henry Grueby, head of the Grueby Faience and Tile Co. of New York on February 23, 1925. Mr. Grueby was intimately associated with the C. Pardee Tile Works, Perth Amboy, N. J. He had been a member of the AMERICAN CERAMIC SOCIETY for a number of years.

George W. Dilks, Jr.

George W. Dilks, Jr., vice-president of the Seaboard Fuel Corporation, Philadelphia, Pa. died on April 16. Mr. Dilks had been the corporation representative for this company in the AMERICAN CERAMIC SOCIETY since 1922.

NOTES AND NEWS

BUREAU OF STANDARDS NOTES

Measurements on the Thermal Expansion of Fused Silica

The Bureau has completed measurements on the thermal expansion of representative samples of fused silica (fused quartz) between minus 125°C and plus 1000°C. The specimens were furnished by commercial companies. This research was undertaken for the purpose of obtaining data on the thermal expansion of fused silica for use in thermostats, clock pendulums, length standards, pyrometers, gas sampling devices, acid resisting articles, insulating and temperature resisting devices, etc.

The expansion curves show very interesting results at low temperatures. For each sample of fused silica, a critical temperature (or minimum length) was found. On heating above this temperature the material expands, but on cooling below this temperature, expansion (instead of contraction, as might be expected) also takes place. In other words, the coefficients of expansion are positive above the critical temperature and negative below this temperature. From a consideration of all available results relating to the critical temperature, or minimum length of fused silica, −80°C may be taken as a representative value for the critical temperature of this material. The results at high temperatures are now being studied.

A manuscript giving the results of this investigation is being prepared for publication. This publication will include a review of available information obtained by previous observers on the thermal expansion of fused silica, as well as a detailed description of the apparatus and methods of measurement required for the accurate determination of such minute values of the coefficient.

SOCIETY OF GLASS TECHNOLOGY

A meeting of the Society of Glass Technology was held in Armstrong College, Newcastle-upon-Tyne, on Wednesday, March 18, the President, S. C. Halse, in the chair. Two papers were presented. The first was entitled, "The Use of Zirconia in Glass-Making and the Characteristics which this Substance Imparts," by Violet Dimbleby, S. English, Edith M. Firth, F. W. Hodkin, and W. E. S. Turner (all of the Department of Glass Technology, the University, Sheffield). Prof. Turner, who gave this paper, referred to the statement by Arnold in 1918 that zirconia had a very low coefficient of thermal expansion, namely 8.4×10^{-7}, only little more than that of fused silica. By analogy with the influence of silica in glass, it might be expected that zirconia would reduce the thermal expansion of glasses and assist in the production of glasses of enhanced thermal endurance. Another reason for investigating the use of zirconia was the possibility of making glass distinctly more durable and resistant to alkaline solutions. Zirconia was also being proposed for use as a refractory material, and had in fact, been employed experimentally for very high temperatures. In recent years it had been advocated as a medium for making opal glasses and enamels, but in the experiments carried out at Sheffield it was found that soda-lime-zirconia-silica glasses and soda-zirconia-silica glasses could be prepared with a considerable zirconia content. In the series of general formula $6SiO_2$ $(2-x)$ Na_2O, x ZrO_2, ten per cent, and in the series $(6-x)$ SiO_2, $2Na_2O$, x ZrO_2, twenty per cent of zirconia was introduced without producing opacity. The glasses containing considerable amounts of zirconia were difficult to melt and were viscous like alumina glasses, but with a shorter working range than the latter. The zirconia glasses did not exhibit low thermal expansion. Their anneal-

ing temperatures increased with zirconia content, less steeply than corresponding glasses with basic oxides, such as lime or magnesia. Replacement of silica by zirconia very considerably enhanced the resistance of the glasses toward attack by alkaline solutions.

The second paper was entitled, "The Effect of Composition on the Viscosity of Glass, Part III. Soda-Lime-Magnesia Glasses, and Soda-Lime-Alumina-Glasses," by S. English. Mr. English described experiments he had carried out with a view to investigating the effect on the viscosity of glass of the substitution of alumina and of magnesia at various temperatures between 1400°C and the annealing temperatures of the glasses produced by substitution. As a starting point, a glass of the molecular composition 1.2 Na_2O, 0.8 CaO, 6 SiO_2 was taken and the lime was substituted by magnesia in molecular proportions, 0.1 mol. being substituted at each stage. Throughout the whole range of temperature, from 1400° to below 600°, the replacement of lime by magnesia was accompanied by a reduction in viscosity, a minimum value being indicated for glasses containing approximately equimolecular proportions of the two bases. A further important feature that was evident from the curves in which the logarithms of the viscosity were plotted against composition for this series of glasses, was that the substitution of magnesia caused the rate of increase of viscosity with falling temperature to become more uniform throughout the whole range of temperature. In the series of glasses in which alumina was substituted molecularly for lime, the viscosity of the melts at 1400° showed increased viscosity, the increase being practically proportional to the molecular proportion of alumina both at 1400° and at 1200°. Below 1200° the substitution of 0.1 lime by 0.1 magnesia caused a decreased viscosity so that at 1000° and 800° there was a distinct minimum value on the viscosity composition curve. Like magnesia, alumina has a pronounced effect in rendering the rate of increase of viscosity with falling temperature more uniform.

TESTS OF IMPURE WATERS FOR MIXED CONCRETE[1]

By Duff A. Abrams

Strength tests of Portland cement concrete were made at ages of 3 days to $2^1/_3$ years using mixing waters of a wide range of types, many of which were thought to be unsuitable for use in concrete. Sixty-eight samples of water were tested in two different investigations; 52 samples were collected from different sections of the country; 14 were from the Chicago district. Among the waters tested were sea and alkali waters, bog waters, mine and mineral waters, waters containing sewage and industrial wastes, and solutions of common salt. Tests of fresh waters (including distilled) were made for purpose of comparison. About 6000 tests are included in this report. Reference is made to a number of other investigations on related subjects.

Series 137: 50 samples of water were used in 1–4 concrete of relative consistency 1.10 and tested after curing under the following conditions:

(*a*) Moist room tested at ages of 3 days to $2^1/_3$ yrs.

(*b*) Moist room 28 days, then in air of laboratory, tested at 3 mo. to $2^1/_3$ yrs.

Series 138: 18 samples including sewage and trade wastes from the Chicago district were used in concrete cured in moist room as follows:

(*a*) 1–7, 1–5, 1–4, 1–3, and 1–2 mixtures; relative consistency 1.00, tested at 28 days.

(*b*) 1–4 concrete mix, relative consistency 0.90, 1.00, 1.10, 1.25, and 1.50, tested at 28 days.

[1] Paper before American Concrete Institute; *Proceedings*, 1924.

(*c*) 1–4 concrete mix; relative consistency 1.00, tested at 3, 7, and 28 days, 3 mo., 1 and $2^1/_2$ yr.

(*d*) 1–3 standard sand mortar, tension tests of briquets and compression tests of 2 by 4-in. cylinders at ages given in (*c*).

Concrete and mortar tests were made in accordance with standard methods. In general, 5 to 10 concrete specimens, and 5 mortar specimens were made in a set on different days.

Time of setting and soundness tests of cement were made with each sample of mixing water.

The principal conclusions from these tests are:

(1) In spite of the wide variation in the origin and type of the waters used, and contrary to accepted opinion, most of the samples gave good results in concrete. This result seems to be due to the fact that the quantity of injurious impurities present is quite small. The following samples gave concrete strengths below the strength-ratio of 85% which was considered the lower limit for acceptable mixing waters: acid waters, lime soak from tannery, refuse from paint factory, mineral water from Colorado, and waters containing over 5% of common salt.

(2) The quality of a mixing water is best measured by the ratio of its 28-day concrete or mortar strength to that of similar mixes with fresh water. While the lowest permissible strength-ratio is a matter of judgment, waters giving strength-ratios which in general fall below 85% should be considered unsatisfactory; if only isolated tests are made, 80% should be the limiting value. The time-of-setting test appears to be an unsafe guide as to the suitability of a water for mixing concrete.

(3) Neither odor nor color are any indication of quality of water for mixing concrete. Waters which were most unpromising in appearance, gave good results. It may safely be said, however, that any natural water which is suitable for drinking can be used without question for mixing concrete.

(4) Distilled water gave concrete strengths essentially the same as other fresh waters.

(5) Bog waters which were thought to be unsuitable for mixing concrete generally contained only small quantities of foreign materials and gave good results. The strength-ratios for the individual samples were seldom below 90%.

(6) Sulphate waters produced little or no ill effects until an SO_4 concentration of about 1% was reached. For a concentration of 0.5% the average reduction in strength was about 4%; a concentration of 1% was required to produce a reduction in strength of more than 10%.

(7) Concrete mixed with sea water (about 3.5% salts, mostly sodium chloride) cured in the moist room gave higher strengths than fresh-water concrete at ages of 3 and 7 days; at 28 days and over, the strength-ratios for sea water ranged from 80 to 88%. Air-cured concrete mixed with sea water was lower in strength than similar fresh-water concrete at 3 mo., but showed a recovery in strength at later ages and gave strengths equal to that obtained with fresh water. (In spite of the satisfactory strength results, it seems unwise to use sea water in reinforced concrete construction, particularly in the tropics on account of danger of corrosion of reinforcement.)

(8) Synthetic sea water gave concrete and mortar strengths similar to natural sea water.

(9) Concrete mixed with water from the Great Salt Lake (about 20% sodium chloride) gave strength-ratios from 65 to 77% at ages of 28 days and over. This water is not satisfactory for mixing concrete, unless allowance is made for about 30% reduction in the assumed strength.

(10) Water from Devil's Lake, North Dakota (0.15% sodium sulphate and 0.15% sodium chloride), gave normal concrete strengths and showed no ill effects.

(11) Water from Medicine Lake, South Dakota (3.5% solution of sulphates, largely magnesium; SO_4 concentration 2.8%), gave strengths similar to that obtained with sea water. The lower strength-ratio was 84%.

(12) Waters from drains and small streams in sulphate districts gave satisfactory strengths at ages up to $2^1/_2$ yrs. The lowest strength-ratios were about 90%.

(13) Concrete made with solutions of common salt and cured until test in a moist room showed a slight increase in strength at 3 days for solutions of 10% and less. Solutions of low concentration (1 and 2%) also showed a slight increase in strength at 7 days; after 7 days, however, all concentrations gave material reductions in strength. Strength-ratios as low as 60% were found for a 20% solution at early ages and for 10% and 15% solutions at the later ages.

Concrete made with salt solutions and cured in the moist room for 28 days, then in air, gave results at 3 mo. almost identical with that obtained for moist-room curing. For this curing condition, the addition of salt reduced the strength at 1 yr. about 12%; at $2^1/_2$ yrs. there was no reduction in strength. The apparently conflicting results for moist-room and air-curing have not been explained.

(14) The use of common salt for the purpose of lowering the freezing point of the mixing water during cold weather should not be permitted; 5% of salt lowers the freezing point of water about 6° F, but reduces the strength of concrete about 30%.

(15) Mine and mineral waters gave good results in concrete, with the exception of a carbonated mineral water from Colorado which gave strength-ratios as low as 80%. Pumpage waters from coal and gypsum mines also gave good results in concrete.

(16) Water containing sanitary sewage gave essentially the same concrete strength as fresh water. Water from the Illinois River, which carries sewage from Chicago, gave strength-ratios at 28 days and 3 mo. of 83 and 85% for moist-room curing; for air-curing strength-ratios ranged from 92 to 102%.

(17) Waters containing refuse from oil refineries gave erratic strengths. These samples generally gave strengths near normal, but in some cases material reductions in strength were found. Setting time of cement with one water sample was: initial 10 hrs., final 42 hrs.

(18) "Bubbly Creek" water, which is highly polluted with wastes from the Chicago Stockyards and gave off an offensive odor showed strength-ratios of about 100% for all ages, mixes and consistencies.

(19) Tannery wastes generally gave reductions in concrete strength; the lowest strength-ratios were about 80% (lime soak water).

(20) Brewery and soap works wastes gave concrete strengths essentially the same as that of fresh water.

(21) Waste from a gas plant and a corn products factory gave good results; the strength-ratios ranged from 90 to 100%.

(22) Paint factory waste water gave strength-ratios ranging from 80 to 90%.

(23) A spent plating bath containing sulphuric acid, after dilution to 10 and 20% of its original concentration, gave strength-ratios as low as 85% for the 10% solution and 74% for the 20% solution. For different consistencies both solutions gave about the same strength-ratios which ranged from 88% to 106%. Lower strength-ratios were obtained with the rich concretes than with the lean.

(24) The strength of concrete mixed with all samples of impure waters showed normal increase at 28 days with additional quantities of cement. The impure waters gave about the same strength-ratios regardless of the mix used in the concrete tests.

For the usual range in mixtures (1–5 to 1–4) the strength increased about 1% for each 1% additional cement.

(25) There was a marked reduction in strength of concrete with increase in quantity of mixing water both for fresh and impure waters. Increasing the quantity of mixing water 1% reduced the strength of concrete about the same amount as if the quantity of cement were *reduced* 1%. A comparatively slight increase in *quantity* of mixing water produced a greater reduction in concrete strength than that caused by the use of the *most polluted* mixing water that is ordinarily encountered. These tests show the importance of the water-ratio strength relation in concrete which has been pointed out in numerous other reports from this Laboratory.

(26) The effect of impure waters was in general independent of the consistency of the concrete. Acid waters from a spent plating bath gave somewhat higher strength-ratios in the wetter concretes.

(27) The strength of concrete cured in a damp condition at normal temperatures increased with age for both fresh and impure waters. The strength was approximately proportional to the logarithm of the age at test.

(28) The effect of impure mixing waters on the tensile and compressive strength of 1–3 standard sand mortar at ages of 3 days to $2^1/_2$ yrs. was generally similar to that on the compressive strength of concrete. In the mortar tests a few waters gave somewhat higher strength-ratios and one water gave a somewhat lower strength-ratio than was obtained in concrete.

(29) The percentage of water required for normal consistency of cement when mixed with the impure waters was, with few exceptions, about the same as for fresh waters. Water from Great Salt Lake, solutions of 5 to 20% of common salt, refuse from an oil refinery, Medicine Lake water, and acid water from a spent plating bath, required somewhat higher percentages for normal consistency than fresh water.

(30) The time of setting of portland cement mixed with the impure waters was about the same as for fresh waters, however, there were some notable exceptions. In most instances the samples giving low concrete strength-ratios were slow setting. On the whole the tests show that time of setting is not a satisfactory test for suitability of a water for mixing concrete.

(31) None of the impure waters caused unsoundness of the portland cement when subjected to the standard test over boiling water.

(32) Most specifications for water for mixing concrete are so worded that they would, if strictly enforced, exclude nearly all but rain water and distilled water; these tests have shown that almost any impurity may be present without *necessarily* producing ill effects. The important point is not whether impurities are present, but do the impurities occur in *injurious* quantities?

(33) The effect of sugar and similar compounds were not studied; earlier tests have shown that these compounds are most detrimental and must be avoided.

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"SCIENCE IN INDUSTRY," RADIO PUBLICATION ISSUED

The University of Pittsburgh has recently issued a pamphlet entitled "Science in Industry" consisting of a series of seven radio talks which were delivered during the winter. Among those who participated in these addresses for the radio were E. Ward Tillotson, Assistant Director, Mellon Institute and President of the AMERICAN CERAMIC SOCIETY, whose subject was "Glass" and MacDonald C. Booze, Senior Industrial Fellow and member of the SOCIETY who talked on "Clay Products." The other addresses in the pamphlet are "Science in Industry" by Edward R. Weidlein, Director of Mellon Institute; "Iron and Steel" by Stephen L. Goodale, Professor of Metallurgy; "Natural Gas" by James B. Garner, Senior Industrial Fellow, Mellon Institute; "Petroleum" by Warren Fred Faraghen, Head of Dept. of Petroleum Refinery Technology, School of Mines; "Coal and Coke" by Frederick W. Speer, Jr., Advisory Fellow, Mellon Institute.

A Select Bibliography is appended to each address and William A. Hamor, Assistant Director of Mellon Institute writes the Introduction. Copies of this publication may be obtained for 60 cents per copy.

CALENDAR OF CONVENTIONS

Organization	Date	Place
Am. Assn. Advancement of Science	Dec. 28–Jan. 2	Kansas City, Mo.
Am. Assn. of Flint and Lime Glass Mfrs.	July, 1925	Atlantic City, N. J.
AMERICAN CERAMIC SOCIETY		
(Annual Meeting)	Feb. 8–13, 1926	Atlanta, Ga.
(Summer Meeting)	July 4–11, 1925	Toronto, Canada
(Fall Meeting)	Oct. 1, 1925	New York City
Am. Electrochemical Soc.	Sept. 24–26, 1925	Chattanooga, Tenn.
Am. Engineering Council	Jan., 1926	
Am. Foundrymen's Assn.	Oct. 5–9, 1925	Syracuse, N. Y.
Am. Gas Assn.	Oct. 12–16, 1925	Atlantic City, N. J.
Am. Inst. of Chem. Engrs.	June 22–25, 1925	Providence, R. I.
	July 13–16, 1925	Leeds, England
Am. Inst. of Min. and Met. Engrs.	Aug. 31–Sept. 5, 1925	Salt Lake City, Utah
Am. Iron and Steel Inst.	May 22, 1925	New York, N. Y.
Am. Mining Congress	May 25–29, 1925	Cincinnati, O.
Am. Soc. of Mechanical Engrs.		
(Spring Meeting)	May 18–21, 1925	Milwaukee, Wis.
(Annual Meeting)	Nov. 30–Dec. 3,	New York City
(Pacific Coast Regional Meeting)	June 22–25, 1925	Portland, Ore.
Am. Soc. for Testing Materials	June 22–26, 1925	Atlantic City, N. J.
Am. Zinc Institute	April 27–28, 1925	St. Louis, Mo.
Assn. Iron and Steel Elec. Engrs.	Sept., 1925	Philadelphia, Pa.
Chemical Equipment Exposition	June 22–27, 1925	Providence, R. I.

Organization	Date	Place
Common Brick Manufacturers Assn.	Feb., 1926	
Glass Container Assn.	April 30–May 2	Atlantic City, N. J.
Institution of Chemical Engineers	July 13–16, 1925	Leeds, England
Manufacturing Chemists' Assn.	June, 1925	New York City
Mining and Met. Society of America	Jan. 12, 1926	New York City
Natl. Assn. of Mfrs.	Oct. 26–28, 1925	St. Louis, Mo.
Natl. Assn. of Stove Mfrs.	May 13–14, 1925	New York City
Natl. Chemical Equipment Assn.	June 22–27, 1925	Providence, R. I.
Natl. Exposition of Power and Mechanical Engrs.	Nov. 30–Dec. 5	New York City
Natl. Lime Assn.	May 26–29, 1925	Briarcliff Manor, N. Y.
Natl. Exposition of Chem. Industries	Sept. 28–Oct. 3	New York City
Natl. Ornamental Glass Mfrs. Assn.	June 4, 1925	Pittsburgh, Pa.
Natl. Paving Brick Mfrs. Assn.	Jan., 1926	
Natl. Safety Council	Sept. 28–Oct. 2	Cleveland, O.
Natural Gas Assn.	May 18–21, 1925	Atlantic City, N. J.
New Jersey Clay Workers Assn.	June, 1925	Trenton, N. J.
Sand-Lime Brick Assn.	Feb., 1926	New Orleans, La.
Sheet Metal Ware Assn.	June, 1925	Cincinnati, O.
Soc. of Chem. Industry	July 13–16, 1925	Leeds, England
Taylor Society	May 14–16, 1925	Ann Arbor, Mich

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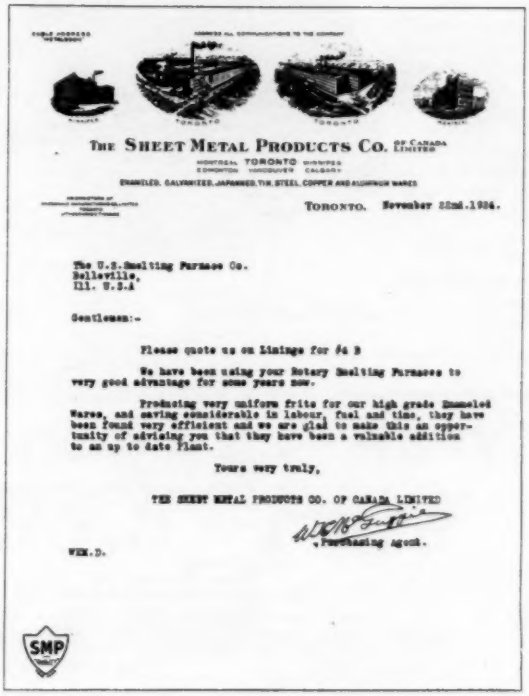

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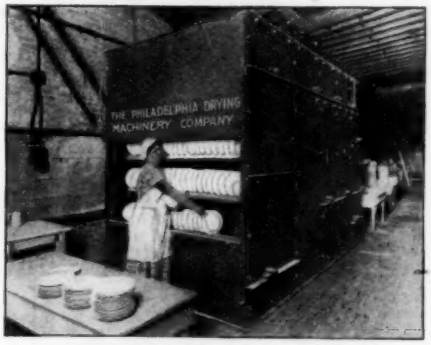

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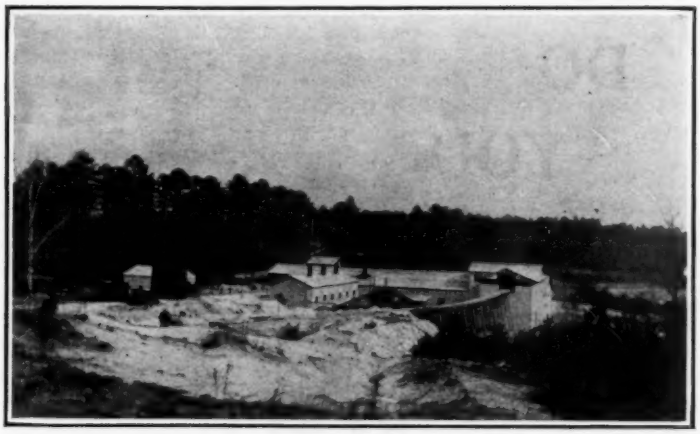

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American Ceramic Society Annual Convention Atlanta, February 8-13th, 1926.

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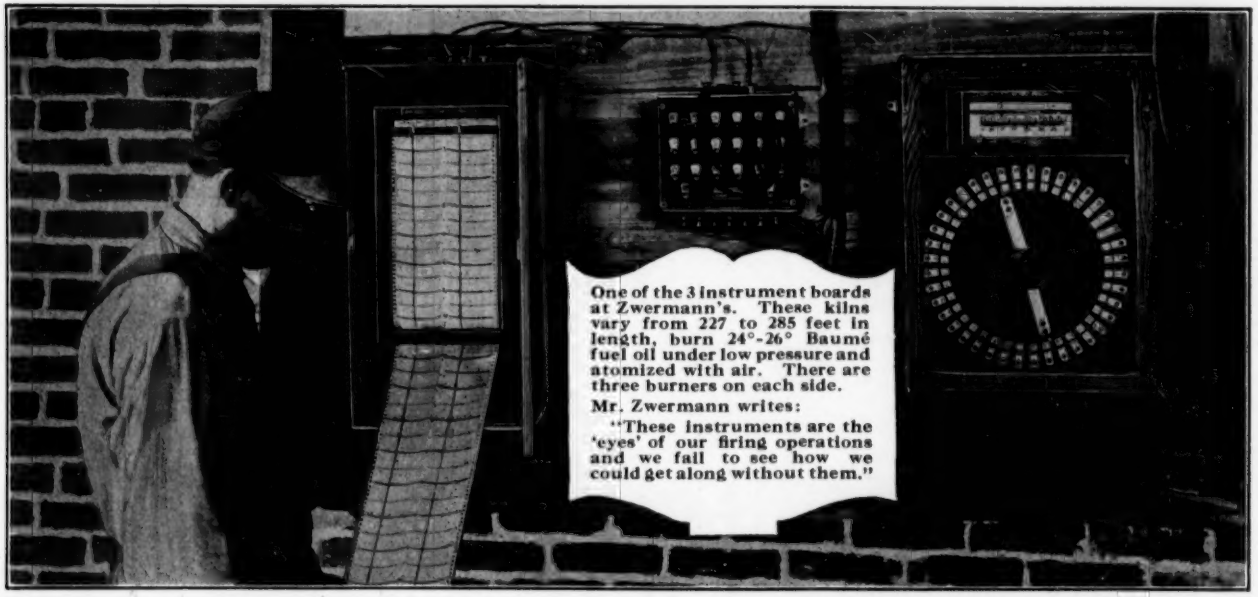

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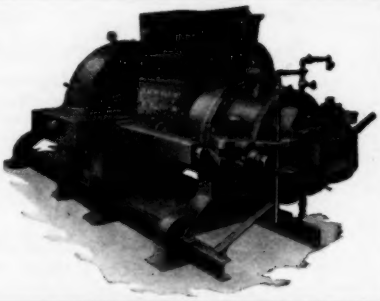

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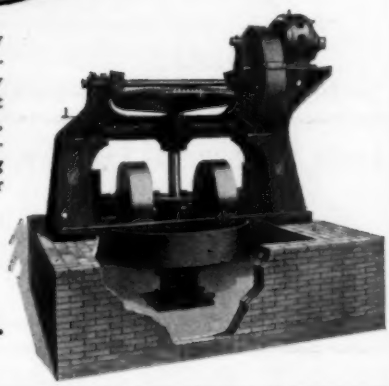

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NEW WIRE CLOTH CATALOGUE

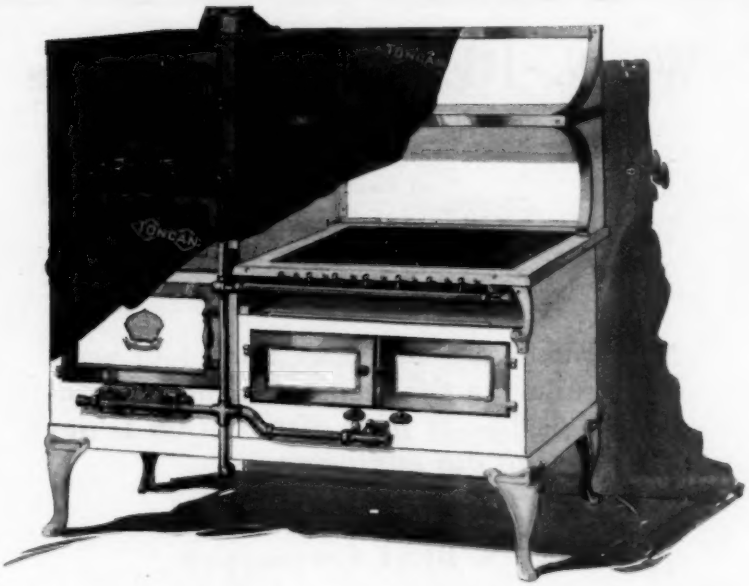
Catalogue, No. 25, Newark Wire Cloth Company.

A new 64-page catalogue, No. 25, has just been published by the Newark Wire Cloth Company, 351-365 Verona Ave., Newark, N. J. The catalogue includes complete information with the list prices on double crimpled heavy steel wire screens; regular coal screens; steel wire cloth; bran duster grade of cloth; timed mill screen cloth; brass, copper and bronze wire cloth; market grade brass and copper wire cloth; and extra fine phosphor bronze wire cloth. It also illustrates several grades and explains in detail the Newark Metallic Filter Cloth which was originated and developed by the Newark Wire Cloth Company and which is now used all over the world. The catalogue goes into the uses of monel metal in considerable detail on two pages, giving a list of sizes of monel metal wire cloth carried in stock. Five pages are devoted to new U. S. Standard Testing Sieves in whose manufacture this company were the world's pioneers. A graph showing the relation between the U. S. Standard and other standards is included as well as price lists of U. S. Standard Sieves and "market grade" testing sieves. In the forepart of the catalogue a photograph of the new factory is shown and a number of pages are devoted to pointers on selecting, ordering and examining of wire cloth. All regular users of wire cloth and all who may have need of it in the future should have a copy of this handy and valuable catalogue on file.

W. W. Sanderson, General Sales Manager of The Carborundum Company, Niagara Falls, N. Y., announces the appointment of Farrand P. Hall as district sales manager in charge of the Carborundum sales organization and branch warehouse at Cleveland, Ohio. Mr. Hall succeeds Mr. John MacArthur who has been district sales manager at Cleveland during the past five years. Mr. MacArthur has been assigned to special sales service work and will be located at the main office of The Carborundum at Niagara Falls. The appointments are effective April 1st.

Mr. Hall joined the Carborundum sales force in 1914 as salesman covering the territory in and about Montreal and the Maritime Provinces. From 1916 to 1922 he was engaged in the retail hardware business and returned to The Carborundum Company in 1922.

Mr. MacArthur has been a member of The Carborundum Sales force since 1909 having been appointed to the sales staff of the Boston, Mass., branch warehouse of the company in February of that year. In January 1919 he was made district sales manager at Cleveland.



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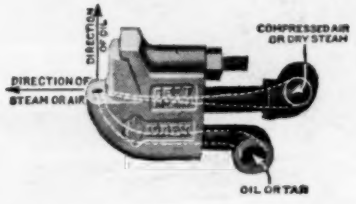

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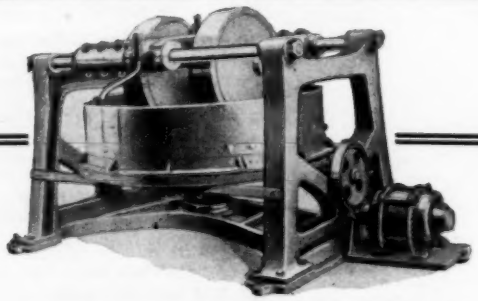

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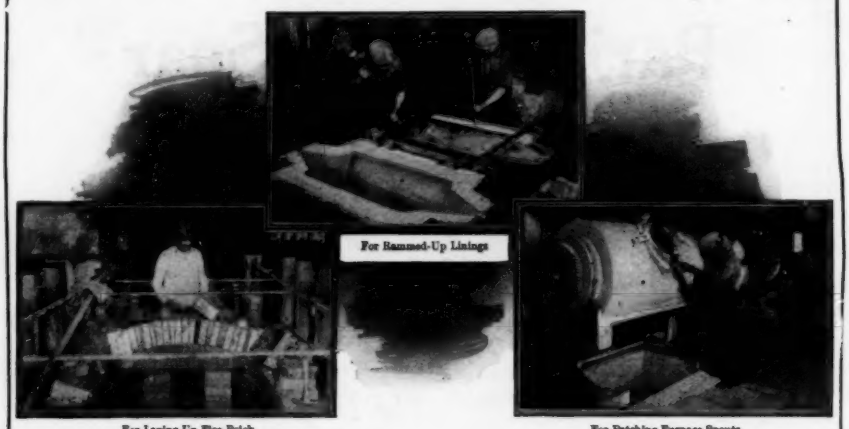

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